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ROTIFERA FROM AUSTRALIAN INLAND WATERS V. LECANIDAE (ROTIFERA: MONOGONONTA)

BY W. KOSTE*, & R. J. SHIEL†

Summary

Diagnostic keys are given to genera and species of the rotifer family Lecanidae (*Hemimonostyla*, *Monostyla*, *Lecane*) recorded from Australian inland waters. All species are figured and available distribution data and ecological information given. Some widely-distributed taxa not yet recorded from the continent are included.

KEY WORDS: Rotifera, taxonomy, Australia, known species, Lecanidae

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KOSTE, W., & SHIEL, R.J. (1990) Rotifera from Australian inland waters. V. Lecanidae (Rotifera: Monogononta). *Trans. R. Soc. S. Aust.* 114(1), 1-36, 31 May, 1990.

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Introduction

In this part of our revision of the Australian Rotifera (Koste & Shiel 1986b, 1987b, 1989a, b) we review the Australian representatives of the family Lecanidae (*Monostyla*, *Hemimonestyla*, *Lecane*), which generally are littoral (epiphytic or epibenthic) in habit. They are common in the shallow vegetated areas of billabongs and other wetlands, with some species (*Monostyla lunaris*, *Lecane luna*) occurring regularly in the plankton communities of open water. In eight billabongs of the Magela Creek, for example, Tait *et al.* (1984) recorded 16 species of *Lecane*/*Monostyla* from a single net tow in Mine Valley billabong (13.vi.79). Such high species diversity is exceptional, a result of concentration as the dry season progressed; more commonly, in temperate Australia, two to four congeners in a collection may be expected.

Diagnostic keys, brief descriptions and figures of all known Australian representatives of the family are provided to enable identification of species. Some widely distributed taxa not yet recorded from Australia are included. The format follows that of earlier parts; dichotomous keys are followed by individual species' descriptions and known Australian records. Relative abundance is indicated by: "common" (more than 30 widely dispersed records), "uncommon" (10-30 localities), "rare" (<10 records). Brief ecological data are included where available. Early Australian records cited in Shiel & Koste (1979) are not repeated here, nor are the majority of northern hemisphere citations given by Koste (1978), which contains a detailed treatment of the Rotifera outside Australia. Keys to families are included in Koste & Shiel (1987b).

Family Lecanidae Bartos

The family was erected by Bartos (1959) to

separate the genus *Lecane* from the taxonomic group containing *Proales*, *Proalinopsis*, *Bryceella* and *Tetrasiphon*. The subgenus *Hemimonestyla* was erected to accommodate lecanids with incomplete fusion of their toes (Bartos 1959: 497-499), *Monostyla* (Ehrenberg), with a single toe, had previously been relegated to subgeneric status (Edmondson 1935). Not all subsequent reviewers accepted subgeneric status for the three groups; their differences are now considered to be sufficiently distinct to warrant generic separation (W.T. Edmondson pers. comm.). Accordingly, we have separated *Monostyla*, *Hemimonestyla* and *Lecane* (s. str.) in the following keys, and rather than provide an exhaustive synonymy, note here that in previous references to species of *Monostyla* and *Hemimonestyla*, authors may have referred either to their nominate genera or *Lecane* (*M.*)/*Lecane* (*H.*) respectively (cf. Koste 1978).

Lorica undivided; foot with three segments, first two fused with ventral plate, only distal segment moveable; one or two toes with free or more or less fused claws. Corona with supraoral buccal area, most without pseudotrochus; mastax malleate, but also capable of a virgate function by means of strong muscles attached to the inner pharyngeal wall. Three genera are recognized in the family.

Key to genera of the family Lecanidae

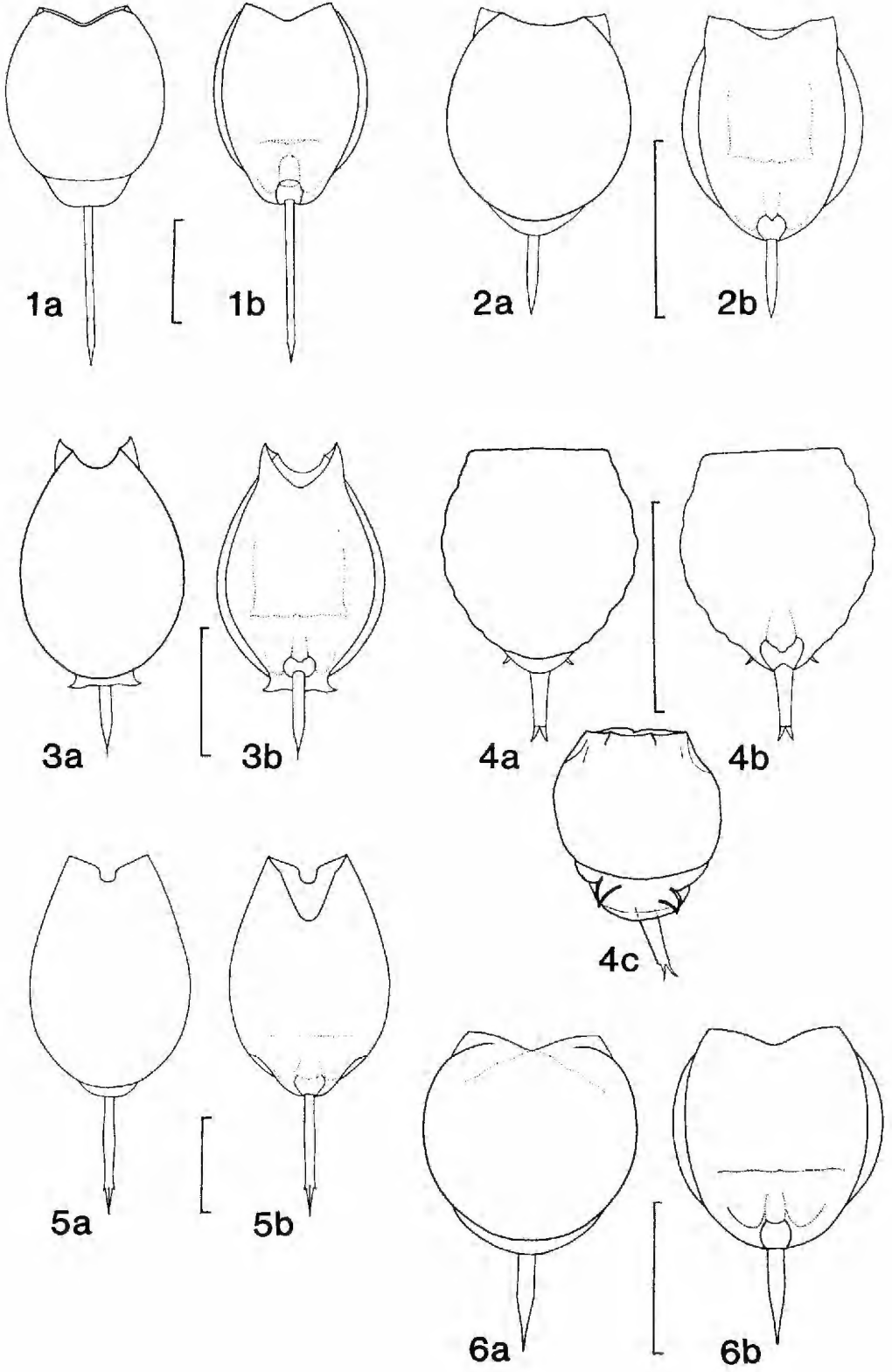
1. Two toes, separated along their full length (Fig. 6:5a)..... *Lecane* Nitzsch, 1827
Single toe or toes partly fused..... 2
2. Distal half of toes separated (Fig. 6:3).....
..... *Hemimonestyla* Bartos, 1959
Single toe (Fig. 1:1).....
..... *Monostyla* Ehrenberg, 1830

Key to species of the genus Monostyla

1. Toe with two claws or a single fused claw... 2
Toe without claw..... 20
- 2(1). Dorsal lorica anterior margin with median curved spines..... *M. quadridentata* Ehrenberg
Dorsal lorica margin without median spines. 3
- 3(2). Lorica anterior margin(s) more or less deeply

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- sinuate 12
 Lorica margin(s) relatively straight 4
 4(3). Claws held tightly together, or fused with only a median groove 6
 Claws diverging, immobile (Fig. 1:4) 5
 5(4). Ventral lorica with paired posterolateral spines ("hip spurs") *M. bifurca* Bryce
 Ventral lorica without hip spurs
 6(4). Toe with only one claw, or indistinct dividing line 7
 Claws separate (Fig. 4:3) *M. obtusa* Murray
 7(6). Dorsal lorica with distinct striations/patterning/ornamentation 8
 Dorsal lorica smooth 10
 8(7). Dorsal and ventral surfaces heavily wrinkled and folded; total length $< 85 \mu\text{m}$ *M. rugosa* Harring
 Regular facettation, less distinct; lorica $> 90 \mu\text{m}$ 9
 9(8). Dorsal facettation regular, each facet bounded by double longitudinal lines; ventral lorica patterned
 Only anterior facet row regular, no double boundaries; no ventral pattern (single transverse fold in front of foot)
 *M. elachis* Harring & Myers
 10(7). Ventral plate constricted just behind anterior margin *M. subulata* Harring & Myers
 Ventral plate not constricted 11
 11(10). Toe spindle-shaped, widest in the middle (Fig. 2:1)
 Toe tapers evenly (Fig. 4:6)
 *M. copeis* Harring & Myers
 12(3). Dorsal and ventral anterior margins concave 14
 Dorsal margin straight, ventral with sinus 13
 13(12). Ventral sinus shallow, with strongly convex sides, externally with two short, stout, incurved hooklike frontal spines (Fig. 5:2)
 *M. stenroosi* (Meissner)
 U-shaped shallow sinus flaring anteriorly, sides not convex; frontal spines absent (Fig. 6:1)
 *M. unguitata* Faddeev
 14(12). Lorica outline nearly circular (Fig. 2:2)
 *M. cornuta* (Müller)
 Lorica outline oval to gooid 15
 15(14). Lorica ovoid, tapers to narrow head aperture ($< \frac{1}{2}$ body width) (Fig. 3:5) 16
 Lorica subcircular to elongate oval, taper less acute, head aperture wide ($> \frac{1}{2}$ body width) (Figs 3:3-5:5) 17
 16(15). Toe long, slender, ca. $\frac{1}{2}$ body length; claw $\frac{1}{4}$ toe length
 Toe $> \frac{1}{2}$ body length; claw extremely long. $> \frac{1}{2}$ toe length *M. stylax* Harring & Myers
 17(15). Lorica $< 120 \mu\text{m}$; toe $> \frac{1}{2}$ body length, long, thin, parallel-sided 18
 Lorica $> 200 \mu\text{m}$; toe $< \frac{1}{2}$ body length, stout with medial bulge
 *M. lamellata thalera* (Harring & Myers)
 18(17). Dorsal and ventral anterior sinuses deep 18
 Dorsal margin only slightly concave; ventral margin with deep U-shaped sinus with convex sides
 *M. crenata* Harring
 19(18). Identical broadly V-shaped sinus in both dorsal and ventral margins, latter projects slightly beyond dorsal margin (Fig. 1:1a)
 *M. acus* Harring
 Ventral sinus deeper than dorsal, rounded at posterior margin (Fig. 3:3)
 *M. lunaris* (Ehrenberg)
 20(1). Lorica with lateral curved spine-like processes
 Lateral processes absent 21
 21(20). Lorica anterior margin with more or less large frontal corner cusps/spines 23
 Front corner cusps absent 22
 22(21). Ventral lorica margin somewhat concave 24
 Ventral lorica margin straight
 *M. pyriformis* Daday
 23(22). Ventral lorica plate in upper third bilaterally constricted
 *M. arcuata* Bryce
 Ventral lorica plate not constricted
 *M. closterocerca* Schmarda
 24(22). Head aperture margins straight, coincident; corner spines small
 Head aperture with dorsal and ventral sinuses of different size; corner spines large 25
 25(24). Posterior segment of ventral lora with sinuate margin and two lateral acute triangular cusps
 *M. batillifer* Murray
 Posterior margin smoothly oval or elliptical 26
 26(25). Dorsal lorica surface smooth, unornamented 27
 Dorsal lorica with regular well-marked facets (Fig. 3:2a)
 *M. humata* Stokes
 27(26). Head aperture with deep, coincident dorsal and ventral margins, flanked by pointed cusps (extensions of ventral lorica)
 *M. decipiens* Murray
 Dorsal anterior sinus shallow, rounded posteriorly with convex edges; ventral sinus a much deeper, narrow cleft (Fig. 5:1b); truncate rather than pointed anterior corners of ventral plate
 *M. sinuata* Häuer

Monostyla acus Harring

FIG. 1:1

Monostyla acus Harring, 1913, p. 398, Pl. 36, Figs 1-3.
Lecane (*M.*) *acus*: Myers 1937, p. 4.

Diagnosis: Head opening with V-shaped sinuses dorsally and ventrally, latter projecting slightly beyond dorsal plate margin; posteriorly, ventral plate extends beyond dorsal margin as broad shield over foot; lateral sulci deep; toe approx. $\frac{4}{5}$ body length, slightly decurved; claw very long.

Total length $180 \mu\text{m}$; dorsal plate $85 \times 82 \mu\text{m}$; ventral plate $100 \times 72 \mu\text{m}$; depth of anterior sinus

Fig. 1. 1, *Monostyla acus* Harring: (a) dorsal; (b) ventral. 2, *M. arcuata* Bryce: (a) dorsal; (b) ventral. 3, *M. batillifer* Murray: (a) dorsal; (b) ventral. 4, *M. bifurca* Bryce: (a) dorsal; (b) ventral. *M. h. entome* (Berzins), dorsal. 5, *M. bulla* Gosse: (a) dorsal; (b) ventral. 6, *M. closterocerca* Schmarda: (a) dorsal; (b) ventral. Fig. 1:1. 2, 3, 4a-b, 5, 6, after Harring & Myers (1926); 4c, redrawn from Berzins (1982). Scale lines $50 \mu\text{m}$.

10 μm ; posterior shield projection 15 μm ; distance between inner edges of lateral sulci 53 μm ; toe 64 μm ; claw 12 μm ; greatest depth of body 38 μm .

Distribution: Palearctic, Nearctic, Indonesia, acidophil in moor and *Sphagnum* pools. Rare: Tas. 16.5–17.0°C, pH 3.1–5.8, 46.2–80.6 $\mu\text{S cm}^{-1}$.

Literature: Koste 1978; Koste & Shiel 1986a.

Monostyla arcuata Bryce

FIG. 1:2

Monostyla arcuata Bryce, 1891, p. 206, text fig.

Lecane (M.) *arcuata*: Pax & Wulfert 1941, p. 143, Fig. 8.

Diagnosis: Head aperture dorsal margin slightly concave, ventral margin with shallow median sinus flanked by two straight sections; transverse fold of ventral plate anterior to foot; toe long and stout, $> \frac{1}{4}$ body length, parallel sided or bulging slightly in middle, then tapering to point. Resembles *M. closterocerca* (Fig. 1:6).

Dorsal plate 45–69 \times 49–63 μm ; ventral plate 60–73 \times 41–50 μm ; toe 23–28 μm .

Distribution: Between moss and algae in springs and flowing waters. Rare: N.S.W., N.T., Qld., Vic. 10.5–28.5°C, pH 5.4–7.9, DO 6.0–10.1 mg l⁻¹, 23–750 $\mu\text{S cm}^{-1}$, 67 NTU, alkal. 2.7 mg l⁻¹.

Literature: Russell 1961; Koste 1978.

Monostyla baillifera Murray

FIG. 1:3

Monostyla baillifera Murray, 1913b, p. 458, Pl. 19, Fig. 2.

Diagnosis: Head aperture with deep V-shaped ventral sinus flanked by large spine-like cusps, dorsally with narrow, shallow U-shaped sinus; ventral plate constricted anteriorly; relatively deep lateral sulci; footplate small, narrow, undulate posteriorly with two distinctive laterally projecting, acutely triangular cusps, projects beyond dorsal plate; toe approx. $\frac{1}{4}$ body length, parallel-sided for $\frac{1}{4}$ of its length, conical posteriorly, ends in bristle-like point.

Total length 120 μm ; dorsal plate 85 μm long; ventral plate 95 μm ; anterior dorsal margin width 17 μm ; ventral margin width 26 μm ; toe 30 μm .

Distribution: Endemic, rare. Described from a pool near Sydney, later recorded also from the N.T.

Literature: Shiel & Koste 1979; Berzins 1982.

Monostyla bifurca entome (Berzins)

FIG. 1:4c

Lecane (M.) *bifurca entome* Berzins, 1982, p. 9.

Diagnosis: Original description and figure inadequate, but as we have not encountered this taxon, are reproduced here: "... the lorica does not [have] a straight frontal margin. It has a very small ring [spinule] on the frontal corners, and the dorsal lorica has a short fold on the occipital

end. The dorsal frontal margin has two not[che]s and the ventral margin has a shallow sinus in the middle." (Berzins 1982:9).

Dorsal plate 50 \times 45 μm ; ventral plate 55 \times 43 μm ; toe 18 μm .

Distribution: Endemic. Only record Creswick Creek, Vic.

Comment: The typical form, *M. bifurca* (Bryce 1892: 274) (Fig. 1:4a, b) is described as follows: Very flexible integument; body length approximately equals width; outline broadly oval; anterior margin straight; lateral sulci lacking; small posterior segment, extending beyond dorsal plate, carries two small lateral spines at sides of foot; toe $> \frac{1}{4}$ body length, tapers distally; claw doubled, spread and immobile.

Dorsal plate 45–54 \times 42–52 μm ; ventral plate 48–58 \times 44–52 μm ; toe 15–19 μm ; claw 3.2–5 μm .

Comment: Of the integument, Haring & Myers (1926:416) noted that it "can not by any stretch of the imagination be called a lorica". *M. bifurca entome* appears loricate, with characteristic margin morphology markedly different from the nominate species. We retain the ssp. ranking as proposed by Berzins until further material is examined to determine if the variant as described represents ecotypic variation, or if specific status is warranted.

Monostyla bulla bulla Gosse

FIG. 1:5

Monostyla bulla Gosse, 1851, p. 200.

Lecane (M.) *bulla*: Wiszniewski 1954, p. 63.

Diagnosis: Head aperture with shallow V-shaped sinus dorsally, U-shaped notch at posterior margin of sinus for protrusion of dorsal antenna; ventral anterior margin with very deep sinus (Fig. 1:5.5b), rounded at posterior end; transverse fold on ventral surface in front of foot; toe long, ca. $\frac{1}{5}$ body length, terminates in slender acute claw with basal spicules; claw with median line, undivided.

Dorsal plate 100–133 \times 74–105 μm ; ventral plate 93–140 \times 68–97 μm ; toe 48–85 μm ; claw to 20 μm ; resting egg 90 \times 70 μm .

Distribution: Cosmopolitan in littoral. Most common lecanid in Australia: eurytopic, pancontinental in billabongs, lake margins, and occasionally in the plankton of reservoirs and rivers, e.g. R. Murray (Shiel *et al.* 1982). 8.0–31.0°C, pH 3.5–9.4, DO 3.0–13.8 mg l⁻¹, 16–6, 600 $\mu\text{S cm}^{-1}$, <1–160 NTU.

Literature: Haring & Myers 1926; Koste 1978.

Monostyla closterocerca Schmarda

FIG. 1:6

Monostyla closterocerca Schmarda, 1859, p. 59, Pl. 14, Fig. 125.

Lecane (M.) *closterocerca*: Edmondson 1935, p. 302.

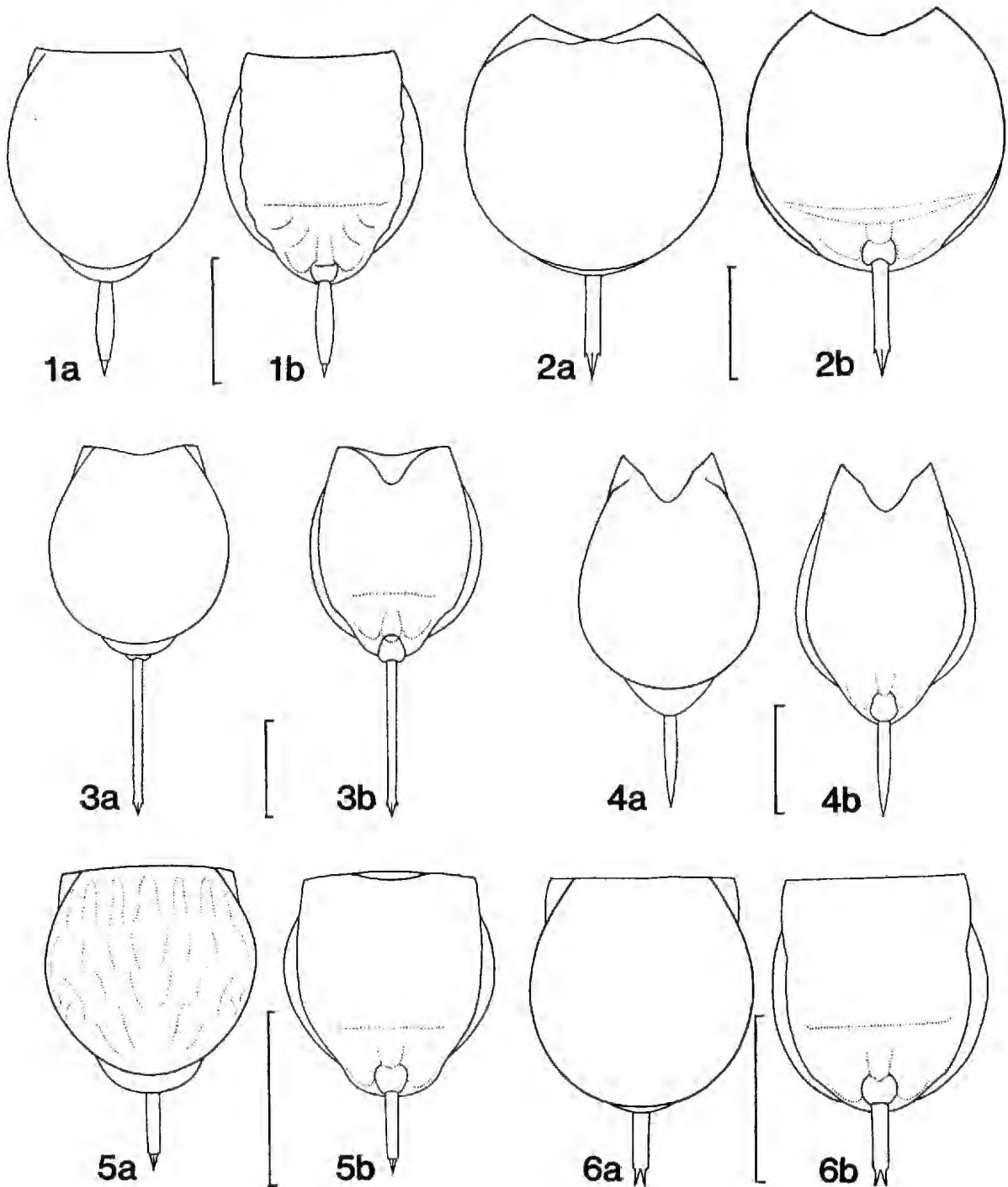
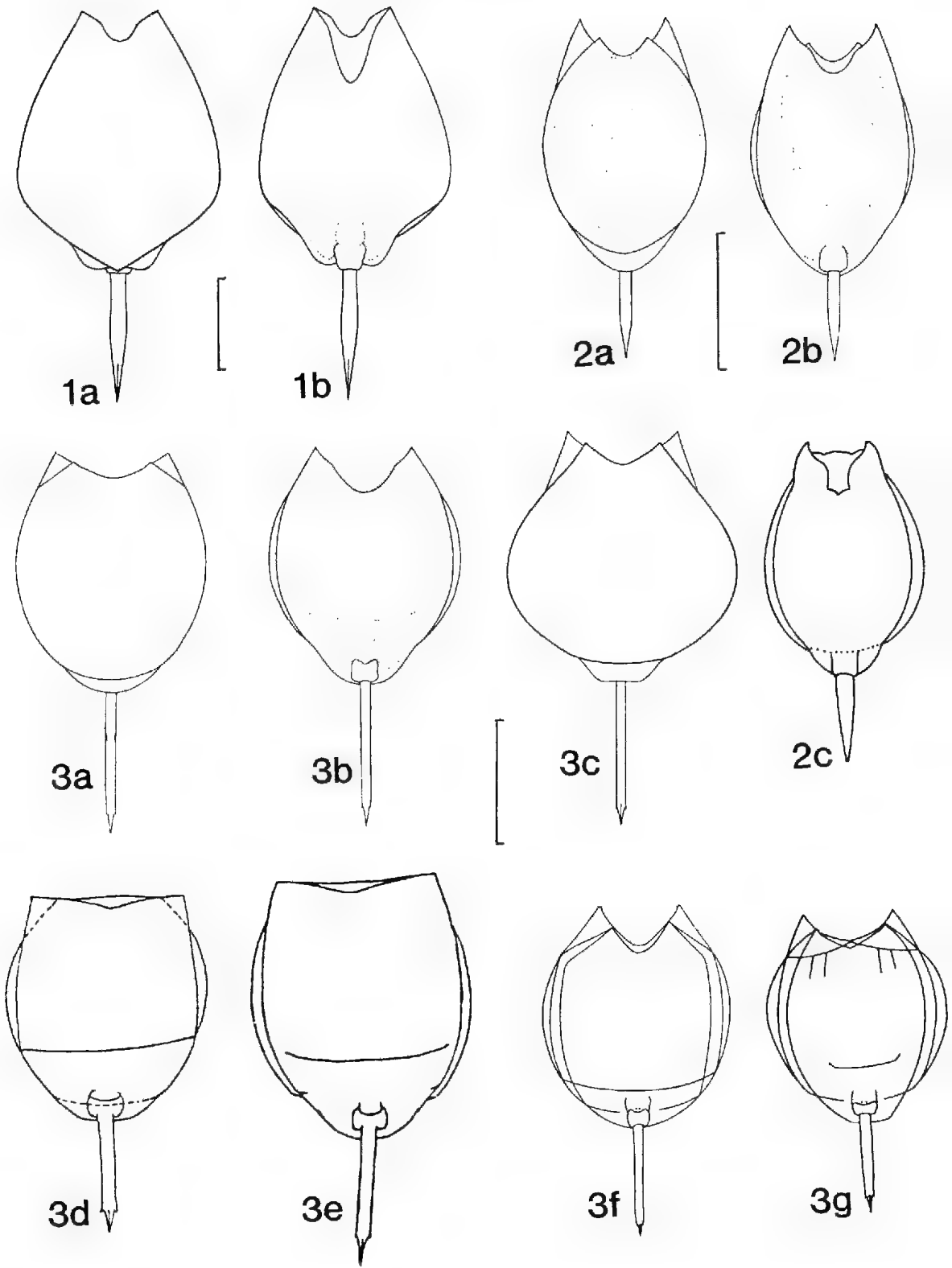


Fig. 2. 1, *Monostyla copeis* Harring & Myers: (a) dorsal; (b) ventral. 2, *M. cornuta* (Müller): (a) dorsal; (b) ventral. 3, *M. crenata* Harring: (a) dorsal; (b) ventral. 4, *M. decipiens* Murray: (a) dorsal; (b) ventral. 5, *M. elachis* Harring & Myers: (a) dorsal; (b) ventral. 6, *M. furcata* Murray: (a) dorsal; (b) ventral. Fig. 2: 1–6, after Harring & Myers (1926). Scale lines 50 μ m.



Diagnosis: Head aperture dorsal and ventral margins similar, shallow V-shaped sinuses with widely flaring convex sides; faint dorsal fold near apex of anterior sinus; transverse ventral fold in front of foot; lateral sulci shallow; toe long, $< \frac{1}{2}$ body length, parallel-sided for $\frac{1}{2}$ length and tapering to slender acute point.

Dorsal plate $54\text{--}85 \times 40\text{--}60 \mu\text{m}$; ventral plate $57\text{--}82 \times 39\text{--}49 \mu\text{m}$; toe $21\text{--}38 \mu\text{m}$.

Distribution: Cosmopolitan in standing and flowing waters, salinity tolerant (to 16 g l^{-1}). In Europe found in branchial chamber of *Astacus fluviatilis*. Common: pancontinental. $11.8\text{--}26.0^\circ\text{C}$, pH $3.4\text{--}7.9$, DO $5.1\text{--}10.3 \text{ mg l}^{-1}$, $42\text{--}6$, $120 \mu\text{S cm}^{-1}$, $0.8\text{--}67 \text{ NTU}$.

Literature: Koste & Shiel 1987a.

Monostyla copeis Harring & Myers

FIG. 2:1

Monostyla copeis Harring & Myers, 1926, pp. 398-9, Pl. 51, Figs 1, 2.

Lecane (M.) copeis: Voigt 1957, p. 238.

Diagnosis: Head aperture margins coincident, slightly concave; transverse ventral fold in front of foot, short curved folds each side of foot; toe spindle-shaped, enlarged in middle, approx. $\frac{1}{2}$ body length, terminating in stout acute claw.

Dorsal plate $75\text{--}88 \times 72\text{--}80 \mu\text{m}$; ventral plate $86\text{--}94 \times 60\text{--}65 \mu\text{m}$; toe $29\text{--}33 \mu\text{m}$; claw $4\text{--}5 \mu\text{m}$.

Distribution: Europe, N. America. Unconfirmed record from Vic.

Literature: Berzins 1982.

Monostyla cornuta (Müller)

FIG. 2:2

Trichoda cornuta Müller, 1786, p. 208, Pl. 30, Figs 1-3.

Monostyla cornuta Ehrenberg, 1830, p. 46.

Lecane (M.) cornuta: Edmondson 1936, p. 214.

Diagnosis: Head aperture with similar deep lunate dorsal and ventral sinuses; angles of sinuses obtuse, without spines; in retracted animal, dorsal fold obvious commencing at base of dorsal sinus, reaching margins behind anterior points; transverse fold in front of foot; toe parallel-sided, ca. $\frac{1}{2}$ body length, terminates in large claw with median groove and two basal spicules.

Dorsal plate $102 \times 88\text{--}110 \mu\text{m}$; ventral plate $85\text{--}128 \times 105 \mu\text{m}$; toe $38\text{--}46 \mu\text{m}$; claw $8\text{--}10 \mu\text{m}$.

Distribution: Cosmopolitan between submerged plants, periphyton. Rare: N.S.W., Qld.

Literature: Sudzuki & Timms 1977; Shiel & Koste 1979.

Monostyla crenata Harring

FIG. 2:3

Monostyla crenata Harring, 1913, p. 399, Fig. 36:4-6.

Lecane (M.) crenata: Voigt 1957, p. 232.

Diagnosis: Head aperture slightly concave dorsally, ventral margin with deep sinus, rounded posteriorly; lorica lateral margins lightly convex, running to frontal corners; deep lateral sulci; toe extremely long, slender $\frac{1}{2}$ body length, straight, parallel-sided, ending in short claw with two basal spinules.

Dorsal plate $90\text{--}120 \times 75\text{--}105 \mu\text{m}$; ventral plate $94\text{--}129 \times 67\text{--}93 \mu\text{m}$; toe $60\text{--}92 \mu\text{m}$; claw $8\text{--}12 \mu\text{m}$.

Distribution: Abundant in tropical and subtropical shallow littorals, thermophile. Rare: N.T., Qld, Vic. 22.5°C , pH 7.5 , DO 7.8 mg l^{-1} , $1,080 \mu\text{S cm}^{-1}$, 3.0 NTU .

Literature: Russell 1961; Koste 1981.

Monostyla decipiens Murray

FIG. 2:4

Monostyla decipiens Murray, 1913a, p. 36, Pl. 15, Fig. 43.

Lecane (M.) decipiens: Wiszniewski 1953, p. 375.

Diagnosis: Head aperture dorsal and ventral margins coincident, with deep V-shaped sinuses, rounded posteriorly; two triangular acute cusps between anterior sinus and edges of lorica; no frontal spines; lateral sulci deep; toe long and slender, $\frac{1}{2}$ body length.

Total length $175 \mu\text{m}$; dorsal plate $76\text{--}116 \times 60\text{--}98 \mu\text{m}$; ventral plate $90\text{--}128 \times 50\text{--}78 \mu\text{m}$; width anterior cusps $44 \mu\text{m}$; toe $25\text{--}48 \mu\text{m}$.

Distribution: Sth and Central America, Sri Lanka, ?Europe. Identified from Nth Qld (C.H. Fernando pers. comm.). Record unverified.

Literature: Chengalath & Fernando 1973; Koste 1978.

Monostyla elachis Harring & Myers

FIG. 2:5

Monostyla elachis Harring & Myers, 1926, p. 406, Fig. 43:1, 2.

Lecane furcata elachis: Wiszniewski 1954, p. 65.

Diagnosis: Head aperture with lightly convex dorsal margin; ventral margin with shallow median concavity, convex towards exterior angles; dorsal lorica ornamented with regular row of facets anteriorly, remainder of surface patterned (Fig. 2:5a); deep lateral sulci; toe $> \frac{1}{2}$ body length, terminating in short, acute claw.

Total length $90 \mu\text{m}$; dorsal plate $62 \times 62 \mu\text{m}$; ventral plate $68 \times 54 \mu\text{m}$; anterior dorsal margin 40

Fig. 3. 1. *Monostyla goniata* Harring & Myers: (a) dorsal; (b) ventral. 2. *M. hamata* Stokes: (a) dorsal; (b) ventral; (c) *M. hamata victoriensis* Koste & Shiel. 3. *M. lunaris* Ehrenberg: (a) dorsal; (b) ventral; (c) another morph, ventral; (d-e) morphs of *M. lunaris perplexa* (Ahlstrom), ventral; (f-g) morphs of *M. lunaris constricta* (Murray), ventral. Fig. 3:1, 2a-b, 3a-c, after Harring & Myers (1926); 2c, after Koste & Shiel (1980); 2d, e after Ahlstrom (1938); 3e-g, after Koste (1978). Scale lines $50 \mu\text{m}$.

μm , ventral 50 μm ; toe 20 μm ; claw 4 μm .

Distribution: Pond littorals, U.S.A., Sri Lanka. Rare: N.T., Tas., 16.0–24.5°C, pH 6.3–7.1 DO 5.8 mg l⁻¹, 59–1020 $\mu\text{S cm}^{-1}$.

Literature: Chengalath & Fernando 1973; Koste 1978.

Monostyla furcata Murray
FIG. 2:6

Monostyla furcata Murray, 1913a, p. 358, Fig. 15:40
Lecane (*M.*) *furcata*: Edmondson 1936, p. 215.

Diagnosis: Ventral and dorsal margins of head aperture straight; ventral plate parallel-sided behind triangular areas extending beyond dorsal anterolateral margins; toe short, stout, $\frac{1}{4}$ body length, terminating in two distinct claws, immobile, separated by V-shaped notch.

Dorsal plate 58–76 \times 57–70 μm ; toe 21–35 μm ; claw 5–6.5 μm .

Distribution: Cosmopolitan in periphyton. Rare: N.T., Qld, Tas., Vic., 15.0–24.5°C, pH 5.3–7.9, DO 5.8–6.12 mg l⁻¹, 28–80 $\mu\text{S cm}^{-1}$.

Monostyla gonata Harring & Myers
FIG. 3:1

Monostyla gonata Harring & Myers, 1926, p. 390, Pl. 37, Figs 5, 6.

Lecane (*M.*) *gonata*: Volz 1957, p. 238.

Diagnosis: Lorica broadly ovate, somewhat angular posteriorly, almost pear-shaped; head aperture resembles that of *M. bulla*, i.e. shallow dorsal V-shaped sinus with median semicircular excision, very deep ventral sinus; dorsal lorica more angular than *M. bulla*, pointed posteriorly; ventral plate narrows in front of foot; posterior segments small, angular, concave terminally; first foot segment broad, indistinct, second segment larger, trapezoidal; toe very long, spindle-shaped, $\frac{1}{2}$ body length, terminating in acute conical point with median line.

Total length 200 μm , lorica length 145 μm , width 115 μm , anterior margin width 40 μm , toe 65 μm .
Distribution: N. America, eastern Europe, shallow waters. Rare: unconfirmed report from western Vic.
Literature: Berzins 1982.

Comment: Although synonymised with *M. bulla* by various authors (e.g. Koste 1978), this taxon is immediately recognizable and separable from that species. The specific status proposed by Harring & Myers is retained here.

Monostyla hamata Stokes
FIG. 3:2a, b

Monostyla hamata Stokes, 1896, p. 21, Pl. 7, Figs 6–8.
Lecane (*M.*) *hamata*: Myers 1937, p. 4.

Diagnosis: Head aperture with narrow U-shaped sinus dorsally; ventrally with deep V-shaped sinus

having two cusps in middle of margins, rounded posteriorly; ventral plate extended anteriorly to form two acute cusps on either side of head aperture; dorsal plate with conspicuous regular faceting; transverse fold and several longitudinal folds on ventral plate.

Dorsal plate 61–88 \times 52–66 μm ; ventral plate 77–98 \times 40–60 μm ; toe 26–38 μm .

Distribution: Cosmopolitan in periphyton, moss pools. Common: probably pancontinental, not recorded from S. Aust. 10.0–30.7°C, pH 3.8–8.4, DO 4.8–13.0 mg l⁻¹, 23–3330 $\mu\text{S cm}^{-1}$, 4–160 NTU, alkal. 1.9–4.1 mg l⁻¹.

Comment: A variant from a Goulburn R. billabong, described as *Lecane* (*M.*) *hamata victoricensis* [Koste & Shiel 1980 (Fig. 3:2c)] has a deep trapezoid notch in the anterior ventral margin, and congruent points of anterior dorsal and ventral margins.

Literature: Shiel & Koste 1979; Green 1981; Koste 1981.

Monostyla lumellata thaleri (Harring & Myers)
FIG. 6:1

Monostyla thaleri Harring & Myers, 1926, p. 394, Fig. 39:3, 4.

M. lumellata thaleri: Koste 1978, p. 254

Diagnosis: Head aperture with concave, sinuate dorsal margin; ventral margin with deep, V-shaped sinus; two small anterior spines at external angles; toe long and stout, $< \frac{1}{2}$ body length, spindle shaped and enlarged near middle; claw long, stout, acutely pointed, with basal spicules and median mucus groove.

Dorsal plate 109–167 \times 90–128 μm ; ventral plate 146–173 \times 90–155 μm ; toe 42–82 μm ; claw to 16 μm .

Distribution: N. and S. America, Europe, N. Africa. Halophile, not found in freshwater. Rare: saline waters in S. Aust., Tas., W.A.

Comment: Described by Harring & Myers (1926) as specifically distinct from *M. lumellata*, which has a lunate anterior ventral sinus and distinctive posterior lateral triangular cusps, however intergrades have been reported in varying salinities. These variants may represent ecotypic responses to extremes in the biotope. Only the *thaleri* morph has been identified from southern Australian saline waters.

Literature: Koste & Shiel 1987a.

Monostyla lunaris Ehrenberg
FIG. 3:3

Monostyla lunaris Ehrenberg, 1832, p. 127.

Lecane (*M.*) *lunaris*: Edmondson 1935, p. 302.

Diagnosis: Head aperture narrow dorsally, with V-shaped posteriorly rounded sinus; ventral margin wide, sinus deep; transverse dorsal fold at base of

anterior sinus; transverse ventral fold in front of foot; toe long and slender, $> \frac{1}{2}$ body length, with two annular constrictions; claw long, slender, acutely pointed, two minute spicules at base.

Dorsal plate $87-115 \times 70-95 \mu\text{m}$; ventral plate $96-122 \times 54-89 \mu\text{m}$; toe $42-76 \mu\text{m}$; claw $6-12 \mu\text{m}$.

Distribution: Cosmopolitan in a remarkable range of habitats: standing and flowing waters, fresh to saline, soda lakes, acid moss pools, etc. Common: pancontinental. $6.0-29.8^\circ\text{C}$, pH $3.1-8.9$, DO $4.9-14.4 \text{ mg l}^{-1}$, $13.4-3330.0 \mu\text{S cm}^{-1}$, $0.4-160 \text{ NTU}$, alkal. 2.3 mg l^{-1} .

Comment: Extremely variable eurytopic species, possibly a species-complex. Recognizable variants recorded from Australia include *M. lunaris constricta* (Murray 1913b) (Fig. 3:3f, g) from the R. Murray at Blanchetown, S.Aust. and *M. lunaris perplexa* (Ahlstrom 1938) (Fig. 3:3d, e) from Victoria. *M. lunaris australis* described by Berzins (1982) from Victoria falls within the range of variation of the parent species and is here synonymized.

Literature: Koste 1978, 1981; Shiel & Koste 1979; Koste & Shiel 1983, 1986a.

Monostyla monostyla Daday

FIG. 4:1

Monostyla monostyla Daday, 1897, p. 143, Fig. 10.

Lecane (M.) monostyla: Wiszniewski 1954, p. 68.

Diagnosis: Head aperture margins straight and coincident; two small spines at external angles; long moveable curved-spines hinged to lateral margin of dorsal lorica, can be rotated and swung back into lateral sulcus when animal swimming, conforming to margin of posterior lorica.

Total length (contracted) $125-153 \mu\text{m}$; dorsal plate $30-58 \times 47 \mu\text{m}$; ventral plate $62-80 \times 46-50 \mu\text{m}$; toe $25-40 \mu\text{m}$.

Distribution: Pantropical and subtropical, also in temperate latitudes in summer. Single record from L. Euramoo, Qld.

Literature: Koste 1978, Green 1981.

Monostyla obtusa Murray

FIG. 4:3

Monostyla obtusa Murray, 1913a, p. 357, Pl. 15, Fig. 37.

Lecane (M.) obtusa: Wiszniewski 1953, p. 378.

Diagnosis: Head aperture margins straight, coincident; two minute frontal spines at external angles; lateral sulci shallow, indistinct; toe $\frac{1}{2}$ body length, slightly enlarged distally; claw long, acutely pointed, with median dividing line, but unseparated; two basal spicules.

Contracted length to $115 \mu\text{m}$; dorsal plate $53-78 \times 45-73 \mu\text{m}$; ventral plate $62-80 \times 45-58 \mu\text{m}$; anterior margin width to $58 \mu\text{m}$; toe $22-40 \mu\text{m}$; claw $6-13 \mu\text{m}$.

Distribution: Cosmopolitan, pH tolerant, eurytopic. Known only from L. Euramoo, Qld, and Yackandandah Creek, Vic.

Literature: Koste 1978; Green 1981.

Monostyla opias Harring & Myers

FIG. 4:2

Monostyla opias Harring & Myers, 1926, p. 411, Pl. 45, Figs 5, 6.

Lecane (M.) opias: Voigt 1957, p. 229.

Diagnosis: Head aperture margins coincident, straight, with two small acute frontal spines; transverse ventral fold in front of foot; toe long, $> \frac{1}{4}$ body length, tapering gradually to bristle-like point.

Contracted length $95-100 \mu\text{m}$; dorsal plate $59-66 \times 54-61 \mu\text{m}$; ventral plate $67-99 \times 42-55 \mu\text{m}$; toe $26-30 \mu\text{m}$.

Distribution: Europe, Americas, between *Sphagnum*, Aufwuchs. Acidophil. Single record Yarra R., McMahoons Creek, Vic., needs confirmation.

Literature: Koste 1978; Berzins 1982.

Monostyla pyriformis Daday

FIG. 4:4

Monostyla pyriformis Daday, 1905, p. 330.

Lecane (M.) pyriformis: Edmondson 1936, p. 214.

Diagnosis: Anterior margins coincident, medially straight or weakly convex, strongly rounded at lateral rims; rudimentary lateral sulci; toes variable, generally dagger-like.

Dorsal plate $51-67 \times 40-60 \mu\text{m}$; ventral plate $53-70 \times 39-49 \mu\text{m}$; toes $22-36 \mu\text{m}$ [Daday (1905) gave toe length of $57 \mu\text{m}$].

Distribution: Cosmopolitan in inundation zones, periphyton, moss, margins of standing and flowing waters. Rare: N.S.W., N.T., Qld, Vic. $14.7-28.5^\circ\text{C}$, pH $5.4-7.1$, DO $4.1-6.2 \text{ mg l}^{-1}$, $23-240 \mu\text{S cm}^{-1}$, 5 NTU , alkal. 2.7 mg l^{-1} .

Literature: Green 1981; Koste 1981; Berzins 1982.

Monostyla quadridentata Ehrenberg

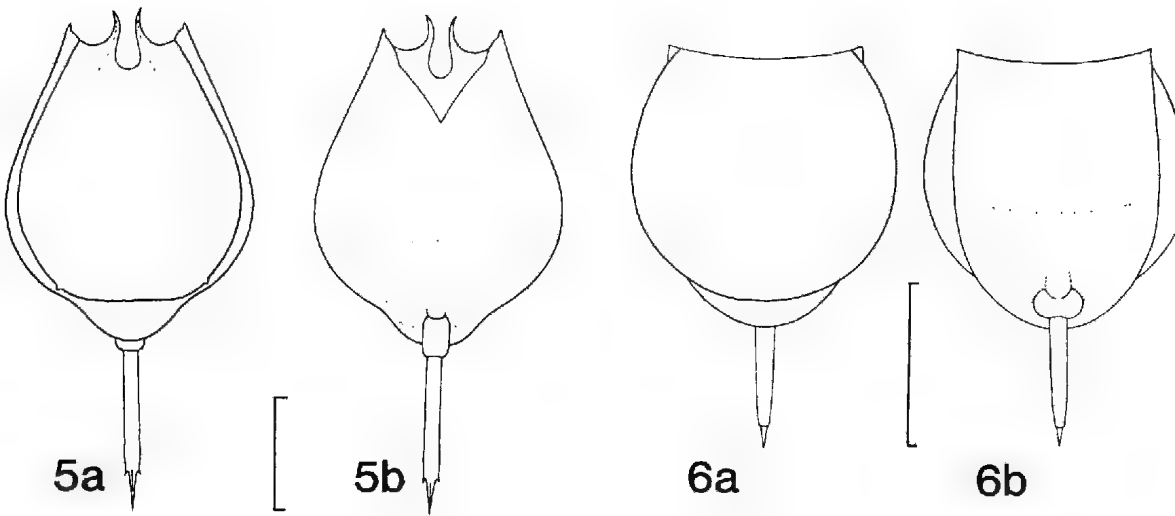
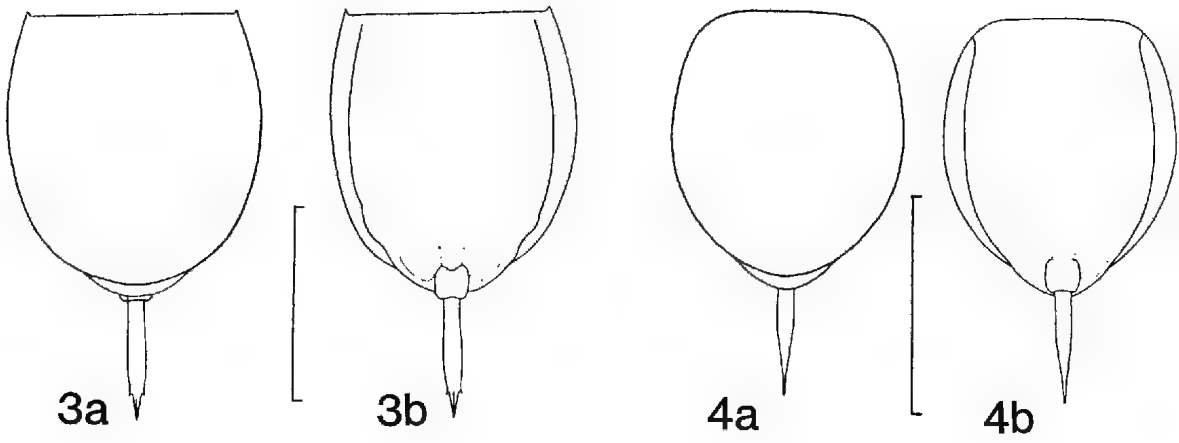
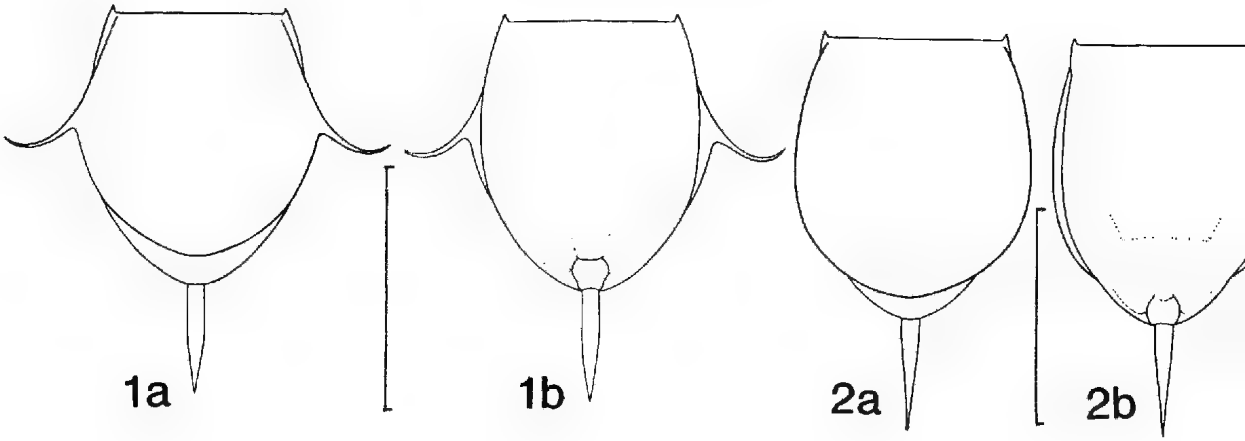
FIG. 4:5

Monostyla quadridentata Ehrenberg, 1832, p. 130.

Lecane (M.) quadridentata: Edmondson 1935, p. 302.

Diagnosis: Anterior dorsal margin with pyriform median sinus flanked by two long outcurved and decurved spines (which can be crossed in strongly contracted individuals); ventral plate with deep, sharply pointed V-shaped sinus; two minute frontal spines present; dorsal plate with two ribs originating on anterior spines; toe long, $\frac{1}{2}$ body length, with indistinct annular constriction near distal end; claw long, slender with two basal spicules.

Dorsal plate $105-106 \times 90-125 \mu\text{m}$; ventral plate $130-170 \times 90-118 \mu\text{m}$; toes $45-90 \mu\text{m}$; claw $14-20 \mu\text{m}$.



Distribution: Cosmopolitan, warm-stenotherm, between macrophytes in littoral or fresh and slightly brackish waters. Rare: N.T., Qld., Tas., Vic., W.A. (Kimberley). 12.0-16.0°C, pH to 8.8, to 3820 $\mu\text{S cm}^{-1}$.

Literature: Koste 1978.

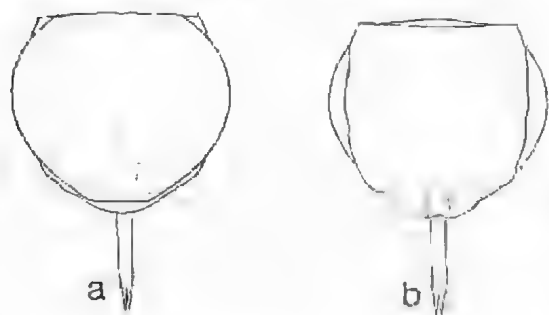


Fig. 5. *Monostyla rugosa* Harring: (a) dorsal; (b) ventral. Scale line 50 μm . After Harring & Myers (1926).

Monostyla rugosa Harring

FIG. 5

Monostyla rugosa Harring, 1914, p. 548, Fig. 24:4-6.

Diagnosis: Head aperture margins nearly coincident, ventral straight, dorsal lightly concave; dorsal plate wider than long, anterior margin narrower than that of ventral plate; dorsal wrinkles deep and irregular; ventral ornamentation constant as shown (Fig. 5b); lateral sulci shallow, indistinct; toe approx. $\frac{1}{4}$ total length terminating in long double claw.

Total length 84 μm , lorica length 57 μm , dorsal plate 54 \times 62 μm , ventral plate width 45 μm , anterior margin dorsal plate 34 μm , ventral plate margin 45 μm , toe 21 μm , claw 6 μm .

Distribution: Panamá, U.S.S.R. First Australian record Ryan's #1 billabong at Albury, N.S.W. 12.88, in *Eleocharis recubens*. 15.8°C, pH 7.16, DO 7.12 mg l⁻¹, 82.2 $\mu\text{S cm}^{-1}$.

Monostyla scutata Harring & Myers

FIG. 4:6

Monostyla scutata Harring & Myers, 1926, p. 401, Pl. 40, Figs. 1, 2.

Lecane (M.) scutata: Wiszniewski 1954, p. 378.

Diagnosis: Head aperture margins coincident, lightly concave; sharp corners but no anterior spicules; lateral sulci shallow, indistinct; transverse fold of ventral plate; toe long, stout, $\frac{1}{2}$ total length, parallel-sided then tapering to slender acute claw.

Dorsal plate 62-78 \times 63-72 μm ; ventral plate 68-80 \times 50-72 μm ; toe 26-34 μm ; claw 5-7 μm .

Distribution: Cosmopolitan acidophil, in *Sphagnum*. Rare: N.I., S. Aust., Tas. 11.0-28.5 °C, pH 5.4-7.8, DO 6.2 mg l⁻¹, alkal. 2.7 mg l⁻¹.

Literature: Koste 1981; Koste & Shiel 1986a.

Monostyla sinuata (Hauer)

FIG. 6:1

Lecane sinuata Hauer, 1938, p. 545, Fig. 67.

L. hamata var. *sinuata*: Koste 1978, p. 259.

Diagnosis: Head aperture conspicuously small, both margins with V-shaped sinuses, but not coincident; dorsal with convex sides, ventral very narrow; twice as deep as dorsal, with straight sides; minute frontal spine on either side of head aperture; dorsal plate smooth, rounded posteriorly; ventral plate same width as dorsal anteriorly, much narrower medially, has transverse fold, longitudinal lines as figured; posterior plate extends beyond dorsal margin; toe $\frac{1}{3}$ body length; no claw.

Dorsal plate 74-76 \times 53-55 μm ; ventral plate 80-82 \times 41-46 μm ; toe 28 μm .

Distribution: Sumatra, India. Rare: Tas. 18.0-21.5°C, pH 6.8-7.7, 92.1-3330 $\mu\text{S cm}^{-1}$.

Comment: Described from a single specimen, *M. sinuata* was noted by Hauer (1938) to resemble *M. hamata* and was so synonymised by Koste (1978). The distinctive head aperture and lack of ornamentation of the dorsal plate renders the species immediately recognizable as distinct from *M. hamata*. The specific determination is retained here.

Literature: Wulfert 1966; Koste & Shiel 1986a.

Monostyla stenroosi Meissner

FIG. 6:2

Monostyla stenroosi Meissner, 1908, p. 22, Fig. 1:8.

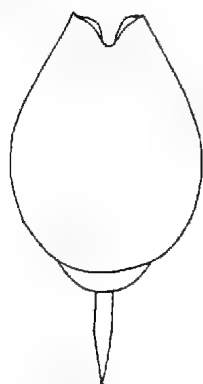
Lecane (M.) stenroosi: Wiszniewski 1953, p. 378.

Diagnosis: Head aperture dorsally straight, ventrally with shallow rounded sinus with strongly convex sides; two short stout, incurved hooklike frontal spines; lateral sulci very deep, particularly in anterior half, with characteristic constriction in ventral plate; toe long, stout $\frac{1}{2}$ body length, slightly enlarged in middle; claw short, stout, acutely pointed, with two basal spicules.

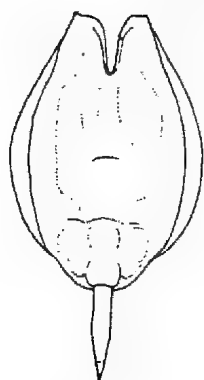
Dorsal plate 90-117 \times 83-100 μm ; ventral plate 98-122 \times 85-103 μm ; toe 40-51 μm ; claw 10-11 μm .

Distribution: Widespread, but isolated. Abundant in algal mats in ephemeral pools, in periphyton and littoral of larger waters. Warm stenotherm. Rare:

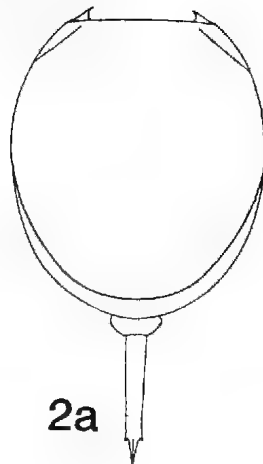
Fig. 4. 1. *Monostyla monostyla* Daday: (a) dorsal; (b) ventral. 2. *M. opus* Harring & Myers: (a) dorsal; (b) ventral. 3. *M. obtusa* Murray: (a) dorsal; (b) ventral. 4. *M. pyriformis* Daday: (a) dorsal; (b) ventral. 4. *M. quadridentata* Ehrenberg: (a) dorsal; (b) ventral. 6. *M. scutata* Harring & Myers: (a) dorsal; (b) ventral. Fig. 4: 1-6, after Harring & Myers (1926). Scale lines 50 μm .



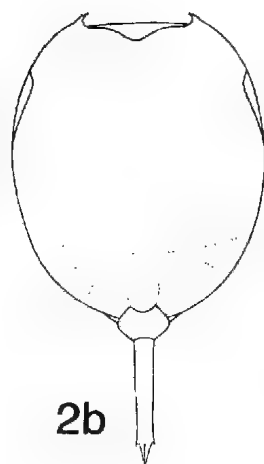
1a



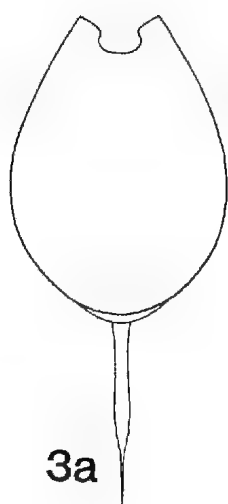
1b



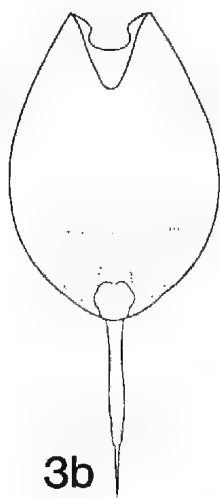
2a



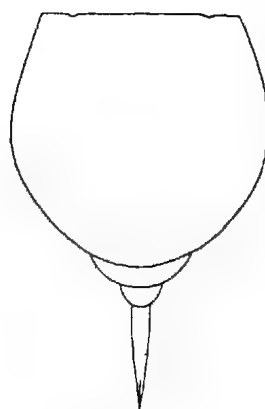
2b



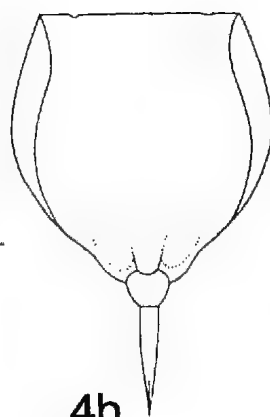
3a



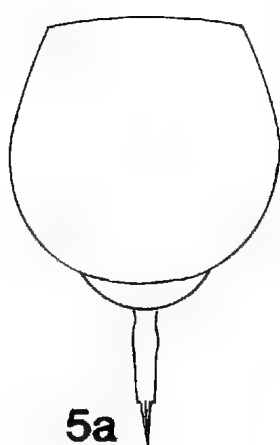
3b



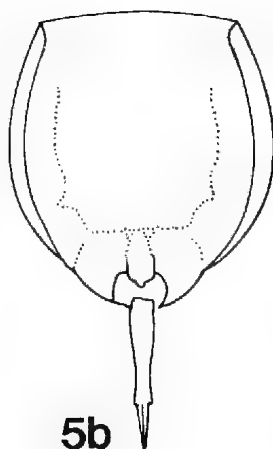
4a



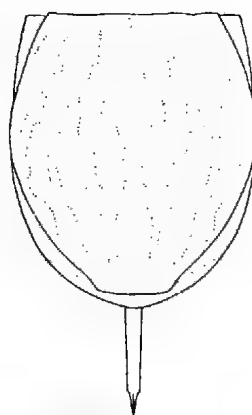
4b



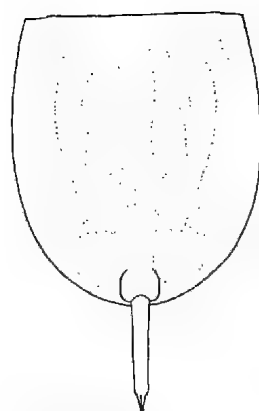
5a



5b



6a



6b

N.S.W., Qld. 13.5–20.0°C, pH 7.5–8.1, DO 7.0–9.0 mg l⁻¹, 400–575 µS cm⁻¹, 50–160 NTU.

Literature: Shiel & Koste 1979.

Monostyla styrax Harring & Myers

FIG. 6:3.

Monostyla styrax Harring & Myers, 1926, p. 389–90, Pl. 37, Figs 3, 4.

Lecane bulla styrax: Myers 1937, p. 2.

Diagnosis: Head aperture narrow, dorsally with wide median elliptic notch, ventrally with deep straight-sided sinus, rounded posteriorly; lateral sulci very deep; toe long, slender, > 1/2 total length, increasing slightly in width in distal half, tapering to blunt point; claw extremely long, slender, acutely pointed. Can be distinguished from *M. bulla* by claw alone, however anterior margin, foot and toe also differ significantly.

Dorsal plate 124×90 µm; ventral plate 128×90 µm; toe 78 µm; claw 24 µm.

Distribution: North America, N.Z. Single record from Qld.

Literature: Russell 1961; Koste 1978; Shiel & Koste 1979.

Monostyla subulata perpusilla (Hauer)

FIG. 6:5

Monostyla perpusilla Hauer, 1929, p. 156, Fig. 14

Lecane (M.) perpusilla: Wiszniewski 1953, p. 378.

L. subulata perpusilla: Koste 1962, p. 113

Diagnosis: Ventral plate bilaterally constricted just under anterior margin; anterior margins lightly convex, coincident; dorsal and ventral surfaces may have indistinct folds; toe long, with distinct constriction in posterior third, > 1/2 body length; claw long, acutely pointed. Large red eyespot, irregularly formed, seen in fresh material.

Total length 69–72 µm; length, dorsal 44–50 µm, ventral 55 µm; width, dorsal to 55 µm, ventral 41–48 µm; anterior margin width 41 µm; toe 19–29 µm; claw 10–11 µm.

Distribution: *Sphagnum*, capillary water of beach sands. Single record from Yarra R. near Ivanhoe, Vic. needs verification.

Comment: The typical form, *M. subulata* Harring & Myers (1926) (Fig. 5:4) has not been recorded from Australia. It can be distinguished from the above taxon by its larger size and relatively shorter toe and claw: Total length (contracted) 87–100 µm; dorsal length 53–64 µm, width 51–65 µm; ventral length 59–68 µm, width 46–55 µm; anterior margin 39–50 µm; toe 16–27 µm; claw 8–10 µm.

Literature: Koste 1978; Berzins 1982.

Monostyla tethis Harring & Myers

FIG. 6:6

Monostyla tethis Harring & Myers, 1926, p. 405, Pl. 38, figs 1, 2.

Lecane (M.) tethis: Wiszniewski 1954, p. 71.

L. furcata var. *tethis* (sic): Koste 1978, p. 242, Fig. 81:7a, b.

Diagnosis: Head aperture with coincident straight dorsal and ventral margins; regular faceting of dorsal plate, with each facet bounded by double longitudinal lines; ventral plate also with longitudinal markings; transverse fold in front of foot, two small semicircular folds; toe long, 1/4 body length, straight with slight taper; claw long, slender.

Total length 100 µm; dorsal plate 70×62 µm; ventral plate 74×62 µm; anterior margin width, dorsal, 42 µm, ventral 53 µm; toe 24 µm; claw 6 µm.

Distribution: Rare in N. America, Central Europe. Single record from L. Euramoo, Qld.

Comment: Synonymised with *M. furcata* by Koste (1978), *M. tethis* lacks the distinctive divided claw of *M. furcata*, and its lorica morphology only superficially resembles that species, which does not have the dorsal and ventral patterning as described. *M. tethis* is of restricted occurrence, probably of precise habitat requirements.

Literature: Koste 1978; Green 1981.

Monostyla unguitata Fátaleev

FIG. 7:2

Monostyla unguitata Fátaleev, 1925, p. 21, Fig. 1:7.

Lecane (M.) unguitata: Wiszniewski 1954, p. 72.

Diagnosis: Head aperture dorsal margin straight, ventral with median U-shaped notch in broad, shallow lunate sinus (Fig. 6:2b); dorsal plate narrower and shorter than ventral; ventral obliquely truncated on end; small front corner spines point inwards as in *M. stenroosi*, toe parallel-sided, slightly swollen distally; claw long, separated or fused.

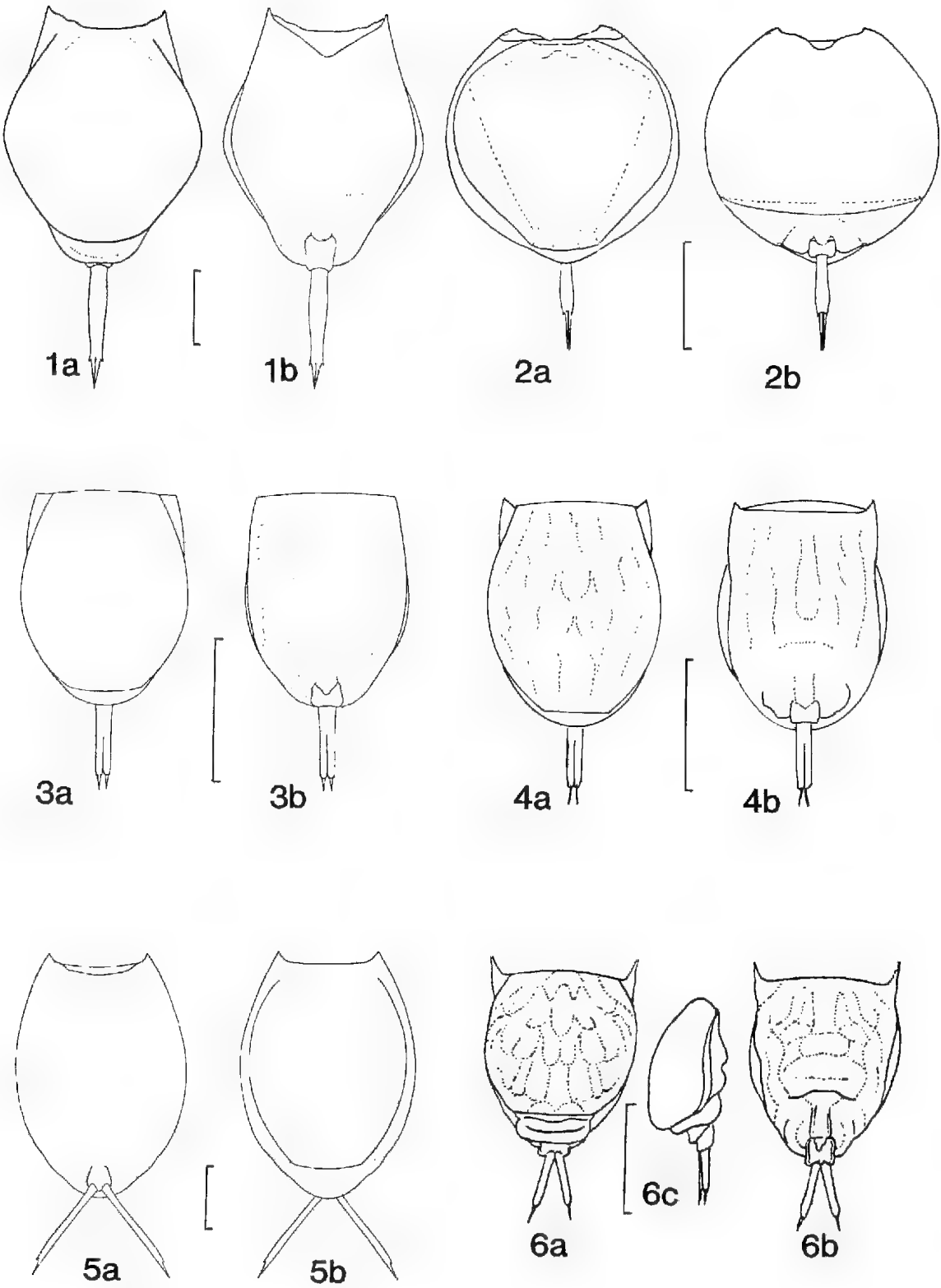
Dorsal plate 83–110×86–92 µm, ventral plate 93–122×93–95 µm; toe 37–44 µm; claw to 15 µm.

Distribution: Rare in East Europe, N. America, Asia, Sri Lanka. Billabongs at Albury, N.S.W., and Jabiluka, N.T. 25.0–31.0°C, pH 6.2–6.3, DO 3.2–10.3 mg l⁻¹, 48–140 µS cm⁻¹.

Comment: A single ?ecotypic variant was identified from a billabong of the Coleman R., Cape York, Qld, lacking the characteristic anterior projections, and slightly smaller in some dimensions.

Measurements: Dorsal, plate 104 × 72 µm; ventral plate 104×83 µm; toe 28 µm; claw 12 µm (Shiel & Koste 1985).

Fig. 6. 1, *Monostyla sinuata* Hauer: (a) dorsal; (b) ventral. 2, *M. stenroosi* Meissner: (a) dorsal; (b) ventral. 3, *M. styrax* Harring & Myers: (a) dorsal; (b) ventral. 4, *M. subulata* Harring & Myers: (a) dorsal; (b) ventral. 5, *M. subulata perpusilla* Hauer: (a) ventral; (b) dorsal. 6, *M. tethis* Harring & Myers: (a) dorsal; (b) ventral. Fig. 6: 1–3, 5, after Harring & Myers (1926); 4, after Hauer (1929). Scale lines 50 µm.



Literature: Hauer 1938; Wulferi 1966; Koste 1978.

Of fourteen taxa of lecanids with part fusion of the toe listed by Koste (1978), only two variants of a single species, *Hemimonostyla inopinata* (Fig. 7:3, 4) are known from Australia. No key is provided for the genus. For details refer to Koste (1978).

Hemimonostyla inopinata (Harring & Myers) FIG. 7:3

Lecane inopinata Harring & Myers, 1926, p. 274, Fig. 12:5, 6.

Diagnosis: Head aperture margins coincident, slightly convex; no frontal spines; dorsal plate smooth, narrower than ventral plate anteriorly, slightly truncate posteriorly; ventral plate with two transverse and several longitudinal ridges; lateral sulci deep; toes long, slender, $\frac{1}{4}$ total length, fused for distal $\frac{1}{5}$ of their length; terminate in distinct claw.

Dorsal plate 56-75×54-62 μ m; ventral plate 59-80×40-58 μ m; toe 21-31 μ m; claws 3-5 μ m.

Distribution: Probably cosmopolitan - subtropical, warm stenotherm. Single record from Wyangala Dam, N.S.W. A record of *H. inopinata sympoda* (Hauer 1929) (Fig. 7:4) from Cairns, Qld (C.H. Fernando pers. comm.) is unverified. Also a warm stenotherm, possibly pantropical, *sympoda* is distinguished from the nominate species by the bilaterally constricted anterior ventral plate, presence of triangular cusps at the anterior corners, and variable lineation of dorsal and ventral plates (see Koste 1978).

Dorsal plate 55-83×49-73 μ m; ventral plate 58-87×48-68 μ m; claws 3-9 μ m.

Key to species of the genus *Lecane*

1. Lorica with acute cusps or rounded projections at anterior-external angles.....3
Lorica without spines or projections at anterior angles.....2
- 2(1). Toes with claws or pseudoclaws.....8
Toes without claws or pseudoclaws.....4
- 3(1). Toes with claws or pseudoclaws.....26
Toes without claws or pseudoclaws.....17
- 4(2). Dorsal plate at least as long or longer than ventral plate.....*L. clara* (Bryce)
Dorsal plate noticeably shorter than ventral plate.....5
- 5(4). Anterior margin almost straight or lightly convex.....16

- Anterior margin (dorsal) with regular undulating lines.....*L. nodosa* Hauer
- 6(5). Toes $\frac{1}{2}$ body length; dorsal and ventral surfaces with complex pattern (Fig. 16:3).....*L. venusta* Harring & Myers
Toes $\frac{1}{4}$ - $\frac{1}{2}$ body length; dorsal surface smooth or sparsely lined, ventral plate with single transverse fold and some longitudinal folds.....7
- 7(6). Lorica wider than long; 2nd foot segment projects well beyond posterior margin.....*L. hornemanni* (Ehrenberg)
Lorica longer than wide; 2nd foot segment beneath lorica margin.....*L. nana* (Murray)
- 8(2). Lorica 180-200 μ m; toes >70 μ m.....9
Lorica <180 μ m; toes <50 μ m.....10
- 9(8). Barrel-shaped lorica (L:W ratio 1.25); broad footplate without marked constriction of lorica margin.....*L. grandis* (Murray)
Lorica more elongate (L:W ratio 1.5), with anterior constriction behind head aperture and marked constriction of margins at footplate.....*L. boorali* Koste & Shiel
- 10(8). Toes long ($\frac{1}{4}$ - $\frac{1}{2}$ body length) - clearly visible beyond footplate.....11
Toes remarkably short (<1/10 body length) barely protruding beyond footplate in dorsal view.....*L. pumila* Rousselet
- 11(10). Lorica elongated (L:W ratio 1.8).....*L. inermis* (Bryce)
Lorica broadly ovate (L:W <1.5).....12
- 12(11). Dorsal and ventral plates distinctly patterned15
Dorsal plates smooth, ventral with single transverse fold or light ornamentation.....13
- 13(12). Claws short (claw:toe ratio <3.0).....14
Claws long (ratio >3.0).....*L. tenuiseta* Harring
- 14(13). Ventral plate with posterolateral corners anterior to footplate producing rectangular appearance.....*L. rultneri* Hauer
Ventral plate posterior margins smoothly curved, without corners.....*L. formosa* Harring & Myers
- 15(12). Claws short (<10 μ m).....16
Claws long (13-18 μ m).....*L. doryssa* Harring
- 16(15). Dorsal plate subcircular; footplate projects beyond dorsal plate to cover 2nd foot segment.....*L. pusilla* Harring
Dorsal plate parallel-sided; 2nd foot segment projects beyond footplate.....*L. subtilis* Harring & Myers
- 17(3). Caudal margin of lorica broadly truncate or rounded.....18
Caudal margin tapering to point, bilaterally constricted tongue or 'fishtail'.....25
- 18(17). Caudal margin straight, with obtuse angled corners.....19

Fig. 7. 1, *Monostyla lamellata thaleri* (Harring & Myers): (a) dorsal; (b) ventral. 2, *M. unguitata* Fadeev: (a) dorsal; (b) ventral. 3, *Hemimonostyla inopinata* (Harring & Myers): (a) dorsal; (b) ventral. 4, *H. inopinata sympoda* Hauer: (a) dorsal; (b) ventral. 5, *Lecane acronycha* Harring & Myers: (a) ventral; (b) dorsal. 6, *L. aculeata* (Jakubskii): (a) dorsal; (b) ventral. Fig. 7: 1, 3-5, after Harring & Myers (1926); 2, after Hauer (1938); 6, after Wulferi (1965). Scale lines 50 μ m.

- Caudal margin smoothly oval/elliptical. 20
- 19(18). Toe <30 μm , short and stout.
 *L. brachydactyla* (Stenroos)
 Toe >30 μm , thin, with finer taper.
 *L. iudicola* Harring & Myers
- 20(18). Second foot segment protrudes at least $\frac{1}{2}$ its
 length beyond caudal margin. 21
 Second foot segment not protruding. 22
- 21(20). Toes <50 μm ; ventral lorica >150 μm
 *L. peticata* Harring & Myers
 Toes <40 μm ; lorica <100 μm
 *L. rhytida* Harring & Myers
- 22(20). Lorica surfaces smooth. 23
 Surfaces (particularly dorsal) clearly ornamented
 *L. signifera* (Jennings)
- 23(22). Frontal margins straight or slightly concave;
 caudal margin smoothly rounded. 24
 Margins deep V-shaped sinuses; caudal margin
 lobate. *L. herzi* Koste & Shiel
- 24(23). Lorica elongated, 200 μm ; toes 75 μm
 *L. pyrrha* Harring & Myers
 Lorica <150 μm ; toes <20 μm
 *L. levistyla* (Olofsson)
- 25(17). Posterior lorica tapers to point.
 *L. ludwigi* (Eckstein)
 Posterior lorica a bilaterally constricted blunt
 tongue, or 'fishtail'. *L. ohioensis* (Merrick)
- 26(3). Frontal corners of lorica with acute spines or
 cusps. 27
 Frontal corner projections rounded rather than
 acute. *L. papuana* (Murray)
- 27(26). Claws with knoblike swelling.
 *L. hastata* (Murray)
 Claws without swelling. 28
- 28(27). Ventral plate with elongated footplate.
 *L. leontina* (Turner)
 Ventral caudal margin symmetrically rounded
 29
- 29(28). Lorica ventral margin projects beyond dorsal.
 *L. elsa* Hauer
 Margins coincident or dorsal projects beyond
 ventral. 30
- 30(29). Dorsal anterior margin straight or lightly convex
 34
 Dorsal anterior margin concave. 31
- 31(30). Head aperture margins coincident V-shaped
 sinuses. 32
 Both margins broad lunate sinuses. 33
- 32(31). Smooth or weakly ornamented lorica; head
 aperture margins smooth.
 *L. curvicaulis* (Murray)
 Both surfaces distinctly ornamented; head
 aperture margin undulate. *L. nitida* (Murray)
- 33(31). Dorsal surface unornamented; no noticeable
 constriction of posterolateral margins at
 footplate. *L. luna* (Muller)
 Dorsal surface stippled; footplate elongated, with
 distinct bilateral constriction of posterolateral
 margins. *L. spenceri* (Shephard)
- 34(30). Dorsal margin straight between cusps, ventral
 margin coincident or lightly concave
 35
 Dorsal margin convex between cusps, ventral
 margin coincident, straight or concave. 38
- 35(34). Distal foot segment not visible beyond lorica
 margin. 36
 Distal foot segment visible beyond lorica margin
 *L. mita* (Murray)
- 36(35). Ventral margin concave; dorsal plate smaller than
 ventral; toes >60 μm long. 37
 Margins coincident; dorsal plate larger than
 ventral; toes <60 μm long.
 *L. tasmaniensis* Koste & Shiel
- 37(36). Claws short (claw:toe ratio >5).
 *L. acronycha* (Jakubski)
 Claws long (ratio <3.5). *L. ungulata* (Gosse)
- 38(34). Last foot segment visible beyond dorsal margin
 41
 Last foot segment not visible beyond margin. 39
- 39(38). Head aperture margins coincident, convex; lorica
 not noticeably elongated. 40
 Dorsal margin convex, ventral concave; lorica
 elongated. *L. glypta* Harring & Myers
- 40(39). Lorica <80 μm long; ventral plate constricted
 anteriorly; small semicircular footplate projects
 slightly beyond posterior lorica.
 *L. flexilis* (Gosse)
 Lorica >100 μm long; ventral plate not
 constricted; footplate broad, extends well beyond
 posterior margin of dorsal plate.
 *L. aspasia* Myers
- 41(38). Ventral plate strongly constricted in 'hip' region
 *L. crepida* Harring
 Ventral plate not constricted. 42
- 42(41). Dorsal plate covers all ventral plate and footplate
 *L. mylactis* Harring & Myers
 Footplate visible posterior to dorsal plate. 43
- 43(42). Cusps large, outer margins convex, pointing
 outwards. *L. aculeata* (Jakubski)
 Cusps small, outer margins concave, point ahead
 or inwards. 44
- 44(43). Toe points short with distinct step on inside
 distinguishing claw. *L. stichaca* Harring
 Toe points elongated, claws indistinct.
 *L. halictysta* Harring & Myers

Lecane acronycha Harring & Myers

FIG. 7:5

Lecane acronycha Harring & Myers, 1926, p. 322, Pl. 8, Figs. 3, 4.

Diagnosis: Dorsal anterior margin straight, ventral slightly concave, with two triangular cusps at external angles; unmarked dorsal plate not reaching margin of ventral plate; transverse fold of ventral

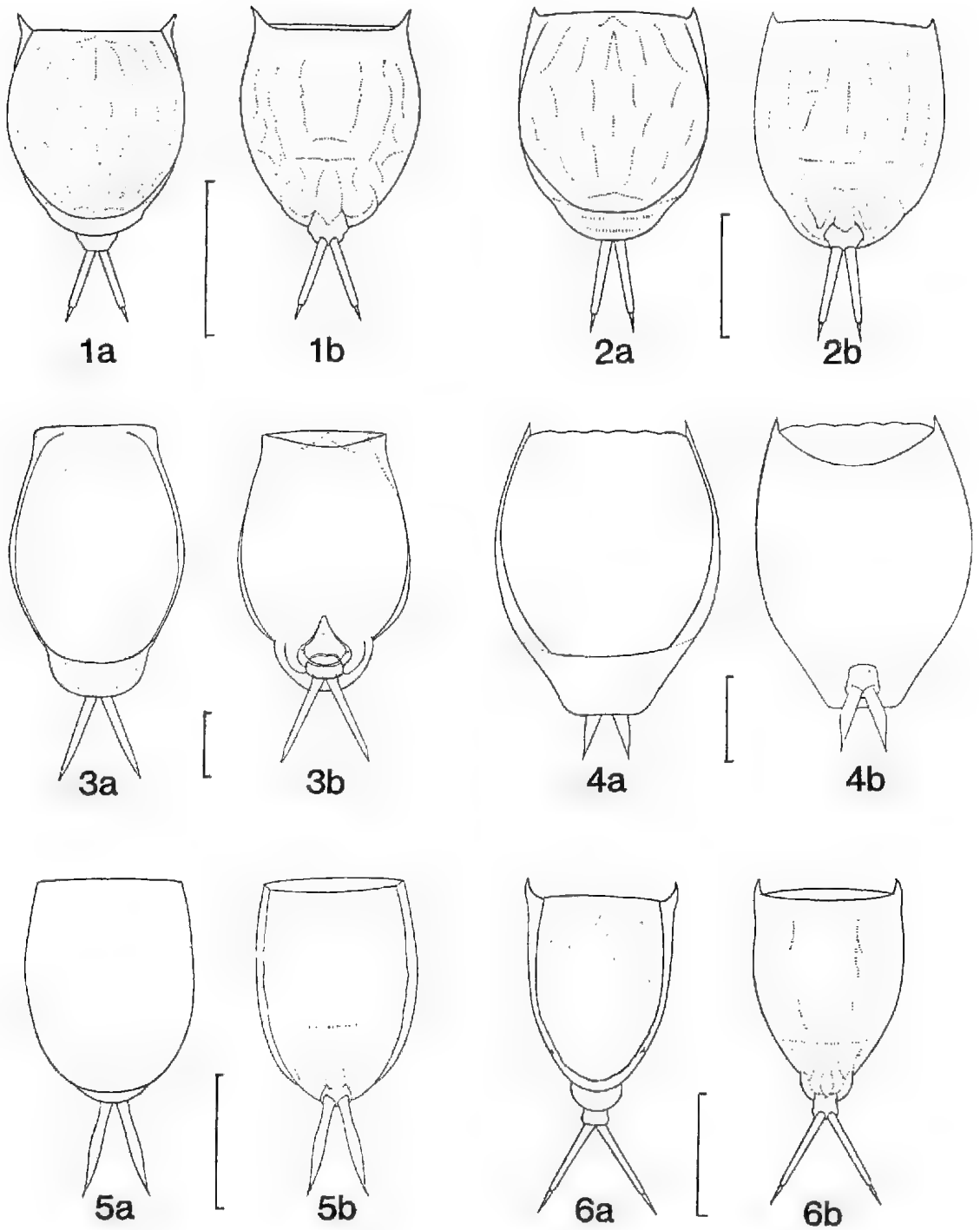


Fig. 8. 1, *Lecane aculeatu arcuata* (Harring): (a) dorsal; (b) ventral. 2, *L. aspasia* Myers: (a) dorsal; (b) ventral. 3, *L. boorali* Koste & Shiel: (a) dorsal; (b) ventral. 4, *L. brachydactyla* (Stenroos): (a) dorsal; (b) ventral. 5, *L. clara* (Bryce): (a) dorsal; (b) ventral. 6, *L. crepida* Harring: (a) dorsal; (b) ventral. Fig. 8: 1, 2, 4–6, after Harring & Myers (1926); 3, after Koste *et al.* (1983). Scale lines 50 μ m.

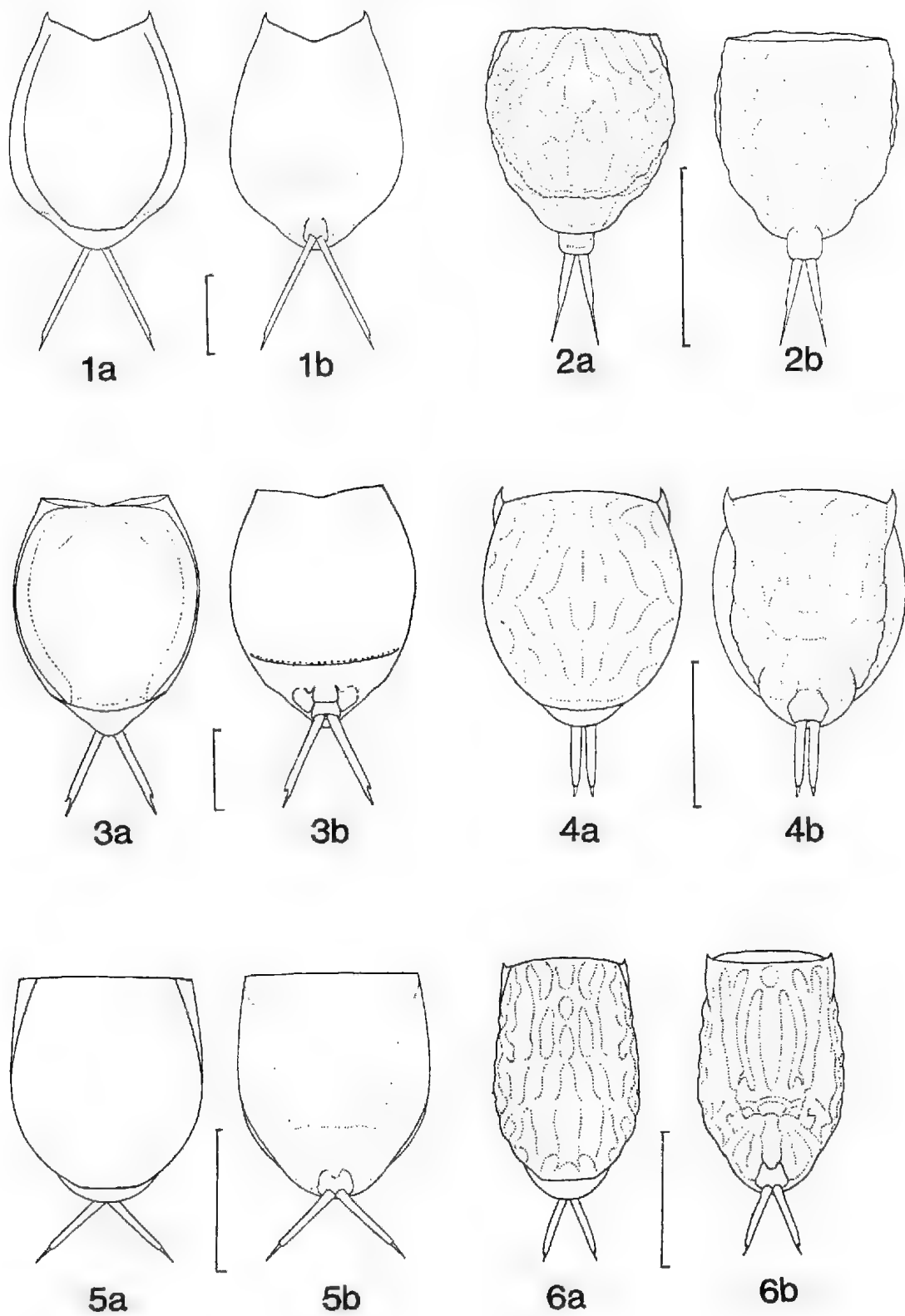


plate anterior to foot; slight indentation of posterolateral margins at footplate; toes long ($> \frac{1}{2}$ body length) with slight distal bulge; claw short, with small basal spicule.

Total length to 290 μm ; dorsal plate 111-162 \times to 136 μm ; ventral plate 125-182 \times 95-113 μm ; toes 60-102 μm ; claw 10-12 μm .

Distribution: N. America, Asia. Acidophil. Two Australian records: billabong, Jabiluka, N.T., river at Kinglake West, Vic. 25.0°C, pH 6.2, DO 3.0 mg l⁻¹, 48 $\mu\text{S cm}^{-1}$.

Literature: Koste 1978, 1981; Berzins 1982.

Lecane aculeata (Jakubski)

FIG. 7:6

Distyla aculeata Jakubski, 1912, p.543, Figs 3, -4.

Diagnosis: Resembles *L. flexilis* (Fig. 8:4), but can readily be distinguished from it by oblique, outwardly directed frontal cusps, narrower lorica, second foot segment visible at posterior end, straight toe and bilaterally constricted needle-like claws. Dorsal plate usually truncated, with two transverse pleats beneath (Fig. 7:6a).

Dorsal plate 62-67 \times 45-55 μm ; ventral plate 73-87 \times 46-52 μm ; toe 22-28 μm ; claw 5-7 μm .

Distribution: Warm stenotherm in subtropical and tropical vegetated waters, particularly ricefields. Rare: Wyangala, N.S.W., Jabiluka, N.T., Qld, southeast S.Aust., Vic. 24.0-27.0°C, pH 6.3-7.4, DO 5.1-7.5 mg l⁻¹, 42-245 $\mu\text{S cm}^{-1}$, 0.5-15.0 NTU.

Comment: A subspecies, *Lecane aculeata arcuata* (Harring) (Fig. 8:1), recorded from Magela Creek, N.T., and Gippsland, Vic. Similar lorica ornamentation, but outline more circular, particularly posterior margin of dorsal plate; transverse pleats posterior to dorsal plate lacking; frontal cusps reflexed upwards; overall dimensions smaller.

Dorsal plate 57-63 \times 49-56 μm ; ventral plate 67-78 \times 44-51 μm ; toe 22-27 μm ; claw 4-6 μm .

Literature: Koste 1978, 1981; Berzins 1982.

Lecane aspasia Myers

FIG. 8:2

Lecane aspasia Myers, 1917, p.476 Pl. 40, Figs 6 & 8.

Diagnosis: Lorica broad, nearly parallel-sided anteriorly, posteriorly rounded; head aperture margins coincident, slightly convex; two small cusps at external angles; posterior segment projects

beyond dorsal plate; toes $> \frac{1}{4}$ body length, straight, tapering; claw long, pointed.

Total length 132 μm ; dorsal plate 82 \times 75 μm ; ventral plate 94 \times 75 μm ; head aperture width 63 μm ; toes 30 μm ; claw 8 μm .

Distribution: California. Single record from Victoria needs verification.

Literature: Berzins 1982.

Lecane horrali Koste & Shiel

FIG. 8:3

Lecane horrali Koste & Shiel, 1983, pp. 14-15, Figs 6-8.

Diagnosis: Head aperture margins not coincident, dorsal straight; ventral concave, occasionally with median V-shaped groove; no cusps at external angles; dorsal plate narrower, shorter than ventral; characteristic triangular depressed foot cavity bounded by raised cuticular ridge (Fig. 8:3b); elongated foot plate depressed from body; toes with laterally opposed claws.

Total length 260 μm ; dorsal plate 180 \times 120 μm ; ventral 200 \times 132 μm ; anterior margin width 100 μm ; toes 82 μm ; claw 10 μm .

Distribution: Endemic; recorded only from a pool near Meekatharra, W.A. pH 8.6, 68 $\mu\text{S cm}^{-1}$.

Lecane brachydactyla (Stenroos)

FIG. 8:4

Cathypna brachydactyla Stenroos, 1898, p.160, Pl. 2, Fig. 20.

Lecane brachydactyla: Harring 1913, p.60.

Diagnosis: Head aperture dorsal margin slightly undulate with prominent lateral cusps; ventral margin with median concavity; lorica dorso-ventrally compressed, no markings; footplate prominent, trapezoidal; toes short, straight on inner edges, with long conical points.

Dorsal plate 100-130 \times 92-115 μm ; ventral plate 128-150 \times 78-119 μm ; toes 20-40 μm .

Distribution: U.S.A., in soft acid waters with *Sphagnum*. Single record from Qld.

Literature: Koste 1978; Shiel & Koste 1979.

Lecane clara (Bryce)

FIG. 8:5

Cathypna clara Bryce, 1982, p.271, text fig.

Lecane clara: Harring 1913, p.60.

Diagnosis: Very flexible membranous lorica; anterior margins not coincident, dorsal lightly convex, ventral concave; no spines at external angles; no markings on dorsal plate; toes long,

Fig. 9. 1, *Lecane curvicornis* (Murray): (a) dorsal; (b) ventral. 2, *L. doryssa* Harring: (a) dorsal; (b) ventral. 3, *L. elsa* Hauer: (a) dorsal; (b) ventral. 4, *L. flexilis* (Gosse): (a) dorsal; (b) ventral. 5, *L. formosa* Harring & Myers: (a) dorsal; (b) ventral. 6, *L. glypta* Harring & Myers: (a) dorsal; (b) ventral. Fig. 9: 1, 4-6, after Harring & Myers (1926); 2, after Hauer (1938); 3, after Hauer (1931). Scale lines 50 μm .

robust, $\frac{1}{2}$ total length, terminating in bristle-like spicule.

Total length 170–200 μm ; dorsal plate 72–83 \times 40–62 μm ; ventral plate 75–90 \times 40–55 μm ; toes 25–40 μm .

Distribution: N. America in *Sphagnum*. Single unconfirmed record from Vic.

Literature: Berzins 1982.

Lecane crepida Harring

FIG. 8:6

Lecane crepida Harring, 1914, p.533, Pl. 22, Figs 4–7.

Diagnosis: Head aperture dorsal margin slightly convex, ventral slightly concave; two short stout incurved cusps at external angles; dorsal plate smaller than ventral, strongly convex; three pairs of divergent wavy ridges on dorsal anterior surface; ventral plate with interrupted longitudinal pleats; no lateral sulci; toes $> \frac{1}{4}$ total length; claw long, slender.

Dorsal plate 75 \times 45 μm ; ventral plate 100 \times 68 μm ; toes 40 μm ; claws 9–10 μm .

Distribution: Often numerous in tropical and subtropical shallow waters. Single record; L. Mulwala, Vic. 24.2°C, pH 7.7, DO 8.6 mg l⁻¹, 60 $\mu\text{S cm}^{-1}$, 22 NTU.

Literature: Koste 1978.

Lecane curvicornis (Murray)

FIG. 9:1

Cathypna curvicornis Murray, 1913a, p.346, Fig. 14:22.

Lecane curvicornis Harring 1914, p.535, Fig. 17:3.

Diagnosis: Head aperture margins coincident, both with broad V-shaped sinuses; two large cusps at external angles; ventral plate much wider than dorsal, with transverse fold; posterior segment rounded; toes $\frac{1}{3}$ total length.

Dorsal plate 110–120 \times 95–112 μm ; ventral plate 130–145 \times 105–116 μm ; toe 48–79 μm ; claw 8–13 μm .

Distribution: Abundant in tropical and subtropical shallow waters. Rare: Finnis R. and Magela Creek, N.T., Coongie Lakes, S.Aust. and southwest W.A. 24.5–29.8°C, pH 5.2–6.3, DO 3.0–6.1 mg l⁻¹, 28–59 $\mu\text{S cm}^{-1}$, alk. 1.9 mg l⁻¹.

Literature: Koste 1978; Berzins 1982; Koste & Shiel 1983.

Lecane doryssa Harring

FIG. 9:2

Lecane doryssa Harring, 1914, p.542, Pl. 21, Figs 4–6.

Diagnosis: Head aperture margins not coincident; dorsal slightly convex, ventral almost straight; no cusps at external angles; dorsal plate faceted, ventral plate with complex pattern (Fig. 8:2b)

posterior segment projects well beyond dorsal plate; $> \frac{1}{2}$ second foot segment projects beyond lorica margin; toes long, slender, reducing to needle-like pseudoclaw at approx. $\frac{1}{2}$ their length.

Dorsal plate 58 \times 60 μm , ventral plate 58 \times 58 μm ; head aperture width 52 μm ; toes 30–32 μm ; pseudoclaw 13 μm .

Distribution: Central Europe, Central America, Amazonia, Asia, Indonesia, in periphyton. Rare: Magela Creek, N.T. and acid waters of western Tasmania. 12.0–29.9°C, pH 3.1–6.3, DO 5.5–5.8 mg l⁻¹, 26–81 $\mu\text{S cm}^{-1}$.

Literature: Koste 1978, 1981; Koste *et al.* (1988)

Lecane elsa Hauer

FIG. 9:3

Lecane elsa Hauer, 1931, p. 8, Fig. 2.

Diagnosis: Head aperture margins not coincident: dorsal convex, ventral biconvex (with median notch); occasionally tiny spines at frontal angles; dorsal plate smooth, smaller than ventral plate; ventral plate with distinct transverse fold; posterior plate with tongue-like elongation over foot segments; lateral sulci deep; toes slender, $< \frac{1}{2}$ body length, tapering to distinct claw.

Dorsal plate 122–140 \times 102–113 μm ; ventral plate 133–160 \times 106–128 μm ; toes 60–66 μm ; claws 9–10 μm .

Distribution: Rare in littoral of large water bodies, but abundant in floodplain waters and inundation zones of central Europe, Amazonia. Rare: N.T., W.A., Vic. 20.0–31.1°C, pH 5.4–7.2, DO 6.7–9.1 mg l⁻¹, 25 $\mu\text{S cm}^{-1}$, Alk. 2.3 mg l⁻¹.

Literature: Koste 1978, 1981; Koste *et al.* 1983.

Lecane flexilis (Gosse)

FIG. 9:4

Distyla flexilis Gosse in Hudson & Gosse, 1886, p. 77, Fig. 24:7.

Lecane flexilis Harring 1913, p.61.

Diagnosis: Head aperture margins coincident, convex, with two short cusps at external angles; dorsal plate faceted, rounded posteriorly; ventral plate narrower than dorsal, less distinctly ornamented; lateral sulci indistinct; toes long, slender, $\frac{1}{4}$ body length, tapering distally to small, acute recurved claw with small dorsal basal spicule.

Dorsal plate 72–76 \times 63–66 μm ; ventral plate 66–90 \times 50–60 μm ; toes 22–50 μm ; claws 3–5 μm .

Distribution: Cosmopolitan, eurytherm, regarded by Koste (1978) as a possible alkalophile, N.T., Tas., Vic., common, abundant in humic acid waters in Tasmania. 8.2–29.0°C, pH 3.1–8.4, DO 6.1–10.7 mg l⁻¹, 9.780 $\mu\text{S cm}^{-1}$, 17.4 NTU.

Literature: Koste 1978, 1981; Koste *et al.* 1988.

Lecane formosa Harring & Myers

FIG. 9:5

Lecane formosa Harring & Myers, 1926, p. 360, Figs 29:1, 2.

Diagnosis: Head aperture margins straight, coincident; no corner spines; dorsal plate smooth, narrower than ventral plate at anterior margin; ventral plate with single transverse fold, two longitudinal lines; posterior segment broadly rounded, projects beyond dorsal plate; toes $\frac{1}{3}$ total length, straight, slightly tapered; claw long, acute, slender.

Total length 110 μ m; dorsal plate 74 \times 68 μ m; ventral plate 80 \times 68 μ m; toes 25 μ m; claws 7 μ m.

Distribution: U.S.A. Single unverified record from

Hunter R., N.S.W.

Literature: Literature: Berzins 1982.

Lecane glypta Harring & Myers

FIG. 9:6

Lecane glypta Harring & Myers, 1926, p. 360, Figs 26:1, 2.

Diagnosis: Head aperture dorsal margin convex, ventral slightly concave, with two small spines at frontal corners; dorsal and ventral surfaces intricately patterned; lateral sulci indistinct; toes $\frac{1}{4}$ total length, slender, parallel-sided; claws small, acute.

Dorsal plate 75-80 \times 50 μ m; ventral plate 80-86 \times 42-46 μ m; toes 22-27 μ m; claws 5 μ m.

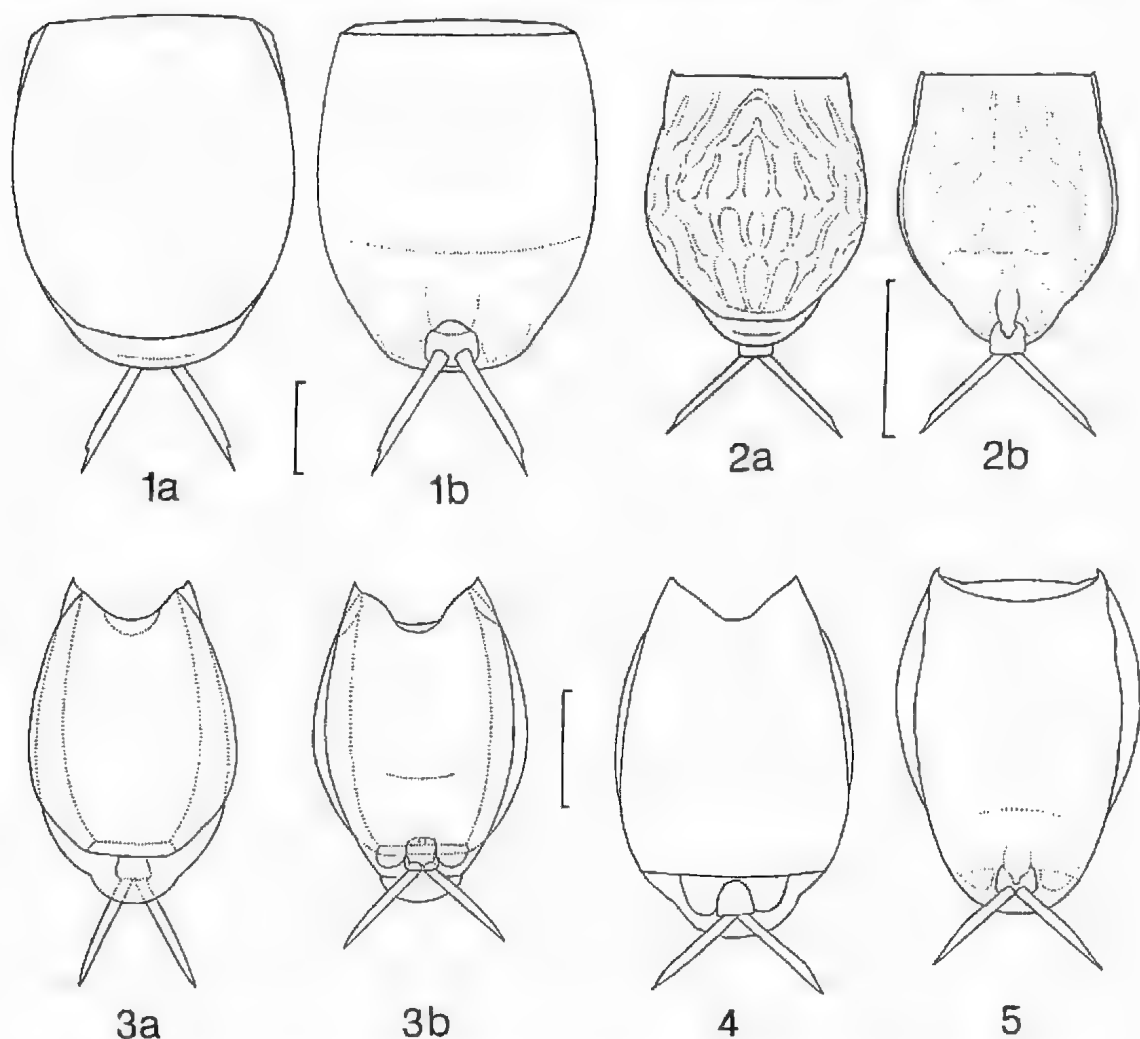
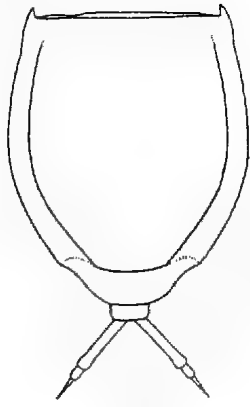
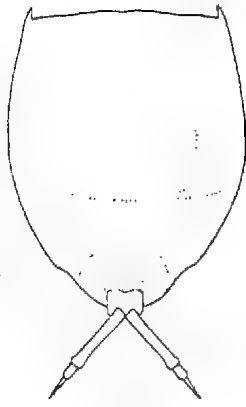


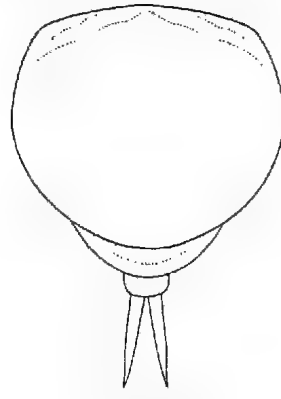
Fig. 10. 1, *Lecane grandis* (Murray): (a) dorsal; (b) ventral. 2, *L. haliclysta* Harring & Myers: (a) dorsal; (b) ventral. 3, *L. herzigii* Koste *et al.*: (a) dorsal; (b) ventral. 4, *L. mitis* Harring & Myers: ventral. 5, *L. ordwayi* Bienert: ventral. Fig. 10: 1, 2, 4, after Harring & Myers (1926); 3, after Koste *et al.* (1988); 5 after Bienert (1986). Scale lines 50 μ m.



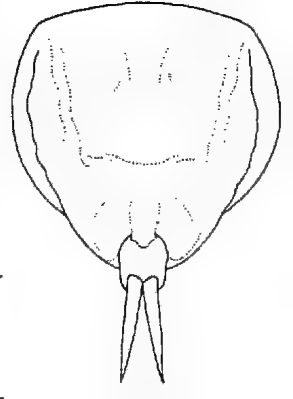
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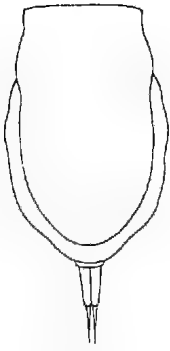
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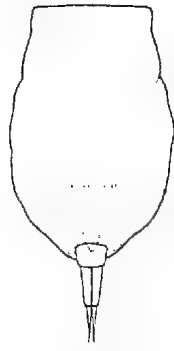
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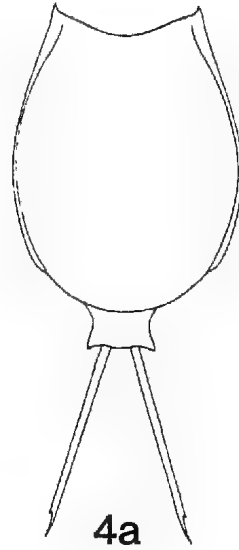
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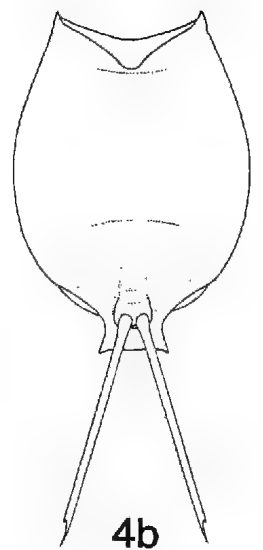
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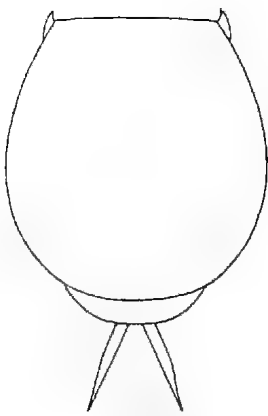
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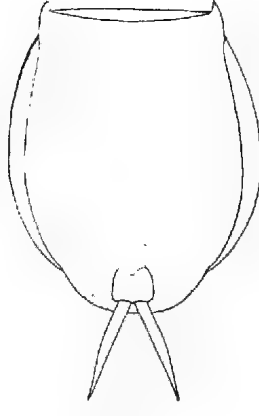
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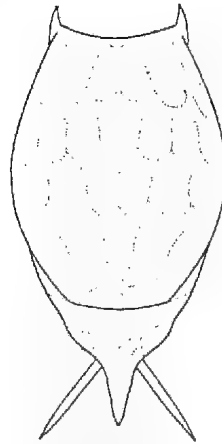
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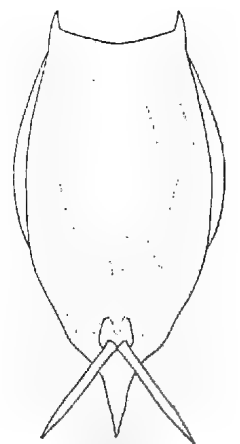
5a



5b



6a



6b

Distribution: N. America, Europe, Middle-East, Asia. Single record, Bichen-Freyinet area, eastern Tasmania. 14°C.

Literature: Koste 1978; Koste & Shiel 1985, 1987a.

Lecane grandis (Murray)

FIG. 10:1

Cathypna grandis Murray, 1913a, p. 344, Fig. 13:20.

Lecane grandis: Fudeev 1925, p. 20, Fig. 1:6.

Diagnosis: Head aperture margins straight; smooth dorsal plate projects slightly ahead of ventral plate; both plates of similar shape; single transverse fold of ventral plate; posterior segment broad, truncate; toes long, blade-shaped; conical claw with basal spicule.

Dorsal plate 165–180×118–140 µm; ventral plate 175–200×118–140 µm; toes 72–80 µm; claws 10–12 µm.

Distribution: Possibly cosmopolitan in brackish/athalassic saline waters. Euryhaline. Single record, billabong, Jabiluka, N.T. 25.0°C, pH 6.2, DO 3.0 mg l⁻¹, 48 µS cm⁻¹.

Literature: Koste 1978.

Lecane halielysta Harring & Myers

FIG. 10:2

Lecane halielysta Harring & Myers, 1926, p. 348, Figs 21:3, 4.

Diagnosis: Head aperture margins coincident, straight, with two small spines at frontal corners; dorsal plate faceted, each facet with double margins; ventral plate also patterned, less regularly than dorsal; caudal plate rounded, projects slightly beyond dorsal plate; toes > ½ body length, straight, ending in indistinct acute claw.

Dorsal plate 71–90×58–78 µm; ventral plate 82–105×56–74 µm; anterior margin 55–160 µm; toes 31–42 µm; claws 8 µm.

Distribution: Europe, Asia, North and South America, rare in soft vegetated waters. Single record: South Esk R., Perth, Tas. 12.7°C, pH 6.0.

Literature: Koste & Shiel 1987a.

Lecane hastata (Murray)

FIG. 11:1

Cathypna hastata Murray, 1913a, p. 348, Fig. 14:25.

Lecane hastata: Harring & Myers 1926, p. 363, Figs 28:5, 6.

Diagnosis: Head aperture margins not coincident; dorsal slightly convex, ventral straight; two small spines at external angles; dorsal plate smaller than ventral, truncate posteriorly; both surfaces finely

stippled; ventral plate also with transverse fold and two longitudinal lines; no lateral sulci; toes long, > ¼ total length, with distal dilation, terminating in long acute claw.

Dorsal plate 74–97×50–79 µm; ventral plate 96–113×74–90 µm; toes 37–41 µm; claws 14–18 µm.

Distribution: Possibly cosmopolitan in periphyton, fresh and slightly saline waters. Recorded in L. Grace, southwest W.A., with a possible record from Cairns, nth Qld (C. H. Fernando pers. comm.).

Literature: Koste *et al.* 1983.

Lecane herzigii Koste, Shiel & Tan

FIG. 10:3

Lecane herzigii Koste, Shiel & Tan, 1988, p. 125, Fig. 12:14.

Diagnosis: Lorica widest medially, ovate; anterior margins with deep rounded sinuses, ventral deeper; short, incurving pointed cusps at external angles; dorsal plate ovate, truncate posteriorly, slightly wider than ventral plate; ventral plate with clearly demarcated posterior lobe commencing at second foot segment; deep lateral sulci; coxal plates small; toes straight to acute point, no claws.

Dorsal plate 96×74 µm, ventral plate 177×70 µm, width anterior margin 41 µm, toes 38–39 µm.

Distribution: Endemic, dune pools, western Tasmania. 17.0°C, pH 3.1–4.3, 80.6–98.3 IS cm⁻¹, 0.5 NTU.

Comment: Although we noted the broad similarity of *L. herzigii* to *L. miftis* Harring & Myers (Fig. 10:4) (Koste *et al.* 1988) we missed the strikingly similar *L. ordwayi* Bienert, 1986 (Fig. 10:5), described from Florida. Comparative measurements are:

Dorsal plate 113–121×88–99 µm, ventral plate 125–142×82–92 µm, width anterior margin 40–52 µm, toes 40–44 µm.

Both *L. herzigii* and *L. ordwayi* were recorded from highly coloured, low pH waters. The affinity of the two taxa may be defined by comparative SEM trophi analysis, however at this time, in view of the morphological differences, we are satisfied that they are not conspecific. *L. herzigii* differs significantly in body proportions, it has a proportionately smaller dorsal plate, with a more elongate, narrower ventral plate, the head aperture margins are more rounded, it lacks a transverse fold above the second foot joint, the lobate posterior segment is distinctive, and there are obvious differences in the coxal region.

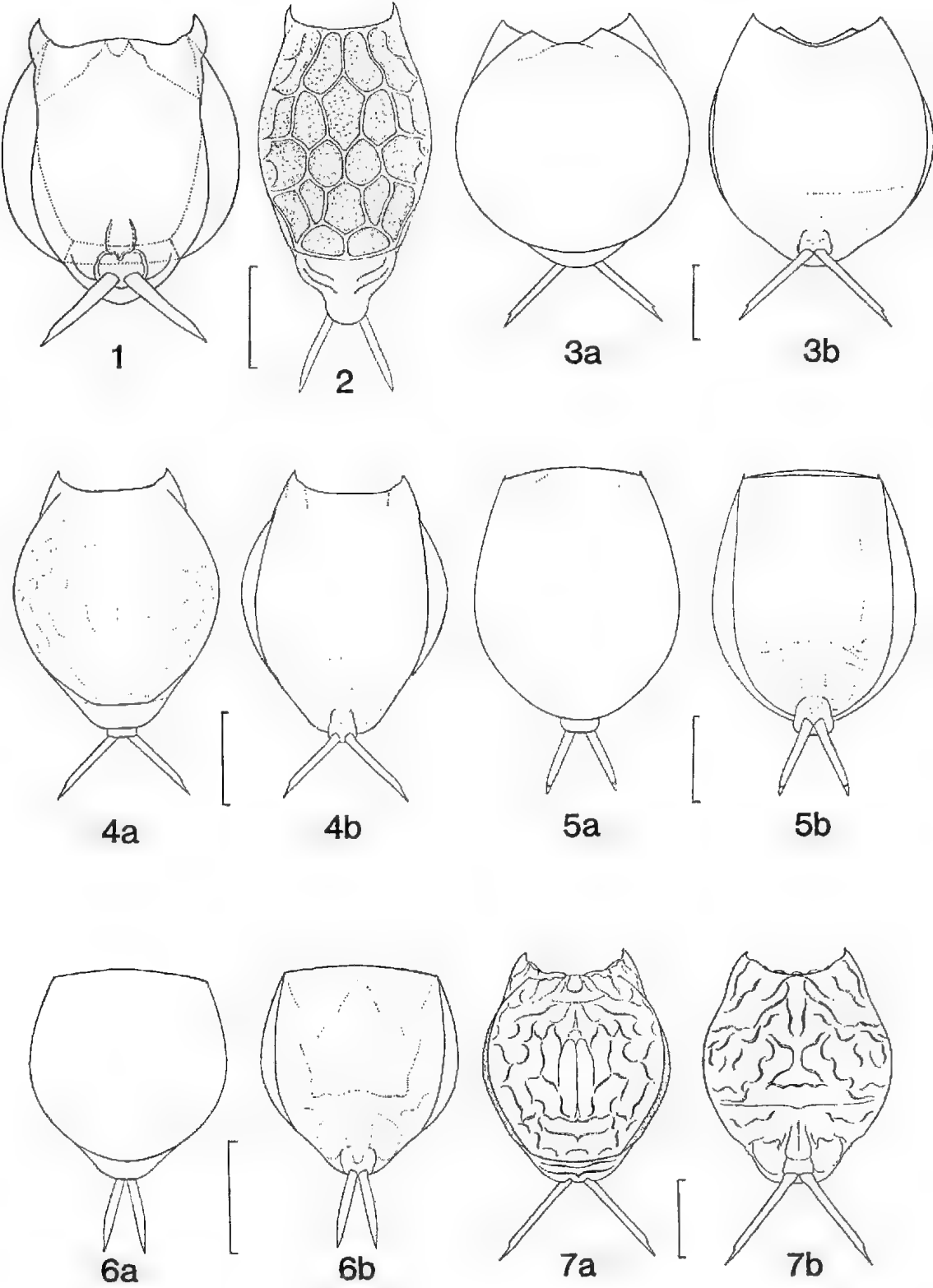
Lecane hornemannii (Ehrenberg)

FIG. 11:2

Euchlanis hornemannii Ehrenberg, 1834, pp. 206, 220.

Lecane hornemannii: Harring 1914, p. 543.

Fig. 10: 1, *Lecane hastata* (Murray): (a) dorsal; (b) ventral. 2, *L. hornemannii* (Ehrenberg): (a) dorsal; (b) ventral. 3, *L. inermis* (Bryce): (a) dorsal; (b) ventral. 4, *L. leontina* (Turner): (a) dorsal; (b) ventral. 5, *L. levinskyi* (Olafsson): (a) dorsal; (b) ventral. 6, *L. ludwigi* (Eckstein): (a) dorsal; (b) ventral. Fig. 11: 1–6, after Harring and Myers (1926). Scale lines 50 µm.



Diagnosis: Lorica broader than long with very deep cross-section; head aperture margins coincident, convex; no frontal cusps; dorsal lorica ornamented with embossed hemispheres corresponding to usual facets (only anterior rows shown on Fig. 11:2a) without distinct demarcations between; ventral plate pyriform with transverse and longitudinal folds; posterior segment projects beyond dorsal plate; second foot segment projects beyond posterior segment; toes $\frac{1}{4}$ total length, tapering to long, conical outcurving points without claws.

Total length 100-140 μm ; dorsal plate 72-110 \times 82-100 μm ; ventral plate 84-115 \times 72-110 μm ; toes 30-35 μm .

Distribution: Widespread in fresh water, particularly tropics and subtropics. Occasionally in slightly saline waters. All states except S.Aust., rare: 19.9-24.5°C, pH 6.3-7.2, DO 5.8-8.5 mg l^{-1} , 59.85 $\mu\text{S cm}^{-1}$.

Literature: Koste 1978, 1981; Green 1981; Berzins 1982; Koste *et al.* 1983; Shiel & Koste 1985.

Lecane inermis (Bryce)

FIG. 11:3

Distyla inermis Bryce, 1892, p. 274, text fig.
Lecane inermis Harring 1913, p. 61.

Diagnosis: Membranous, very flexible lorica; anterior margins coincident, (usually) straight; ventral plate wider than dorsal, both without ornamentation; foot segment rounded, projects beyond dorsal plate; second foot segment projects beyond lorica; toes short, straight, terminate in acute recurved claw almost as long as toe.

Total length 92-154 μm ; dorsal plate 52-80 \times 36-48 μm ; ventral plate to 96 \times to 48 μm ; toes 14-16 μm ; claws 10-12 μm .

Distribution: In athalassic saline waters, in thermal springs and warm waters, eurytopic (pH 4.8-10.0, 5.9-43.0°C) (Koste 1978). Kutikova (1970) recorded *L. inermis* from a geyser at 62.5°C. Rare; not recorded in this study, but noted by Berzins (1982) from several localities in Victoria (presumably cooler waters: April, July).

Lecane leontina (Turner)

FIG. 11:4

Cathypna leontina Turner, 1892, p. 61, Fig. 1:12.
Lecane leontina Harring 1913, p. 61.

Diagnosis: Head aperture margins not coincident; dorsal concave, ventral with broad V-shaped sinus, rounded at apex; two small cusps at external angles; dorsal plate unornamented, ventral with indistinct

transverse fold; posterior segment protrudes over foot as a quadrangular plate with undulate posterior margin or two divergent lateral spines; toes extremely long, almost body length, terminating in long claw with basal spine.

Dorsal plate 138-170 \times 115-147 μm ; ventral plate 168-249 \times 118-152 μm ; toes 92-154 μm , claws 11-15 μm .

Distribution: In vegetated shallow waters, tropical and subtropical lake littorals. Rare, possibly widespread in northern Australia, although records are few: N.T., Qld, S.Aust. (Coongie Lakes), W.A. (Kimberley) (last two records: Shiel unpubl.). 24.0-25.0°C, pH 6.0-6.3, DO 5.1-5.8 mg l^{-1} , 42-59 $\mu\text{S cm}^{-1}$.

Literature: Shiel & Koste 1979; Koste 1981.

Lecane levistyla (Olofsson)

FIG. 11:5

Cathypna levistyla Olofsson, 1917, p. 280, Fig. 10.
Lecane scobis Harring & Myers, 1926.

Diagnosis: Head aperture margins not coincident; dorsal straight, ventral concave; incurved small cusps at external angles; ventral plate narrower than dorsal, both unornamented; second foot segment projects slightly beyond dorsal margin; toes $> \frac{1}{4}$ total length, tapering from $\frac{1}{2}$ their length to acute points (no claw).

Dorsal plate 95-115 \times 93-113 μm ; ventral plate 110-140 \times 61-100 μm ; toes 35-45 μm , claws 15-18 μm .

Distribution: Cosmopolitan in inundation areas. Rare: single record from Magela Creek, N.T. 28.5°C, pH 5.4, DO 6.2 mg l^{-1} , 23 $\mu\text{S cm}^{-1}$.

Literature: Koste 1978, 1981.

Lecane ludwigi (Eckstein)

FIG. 11:6

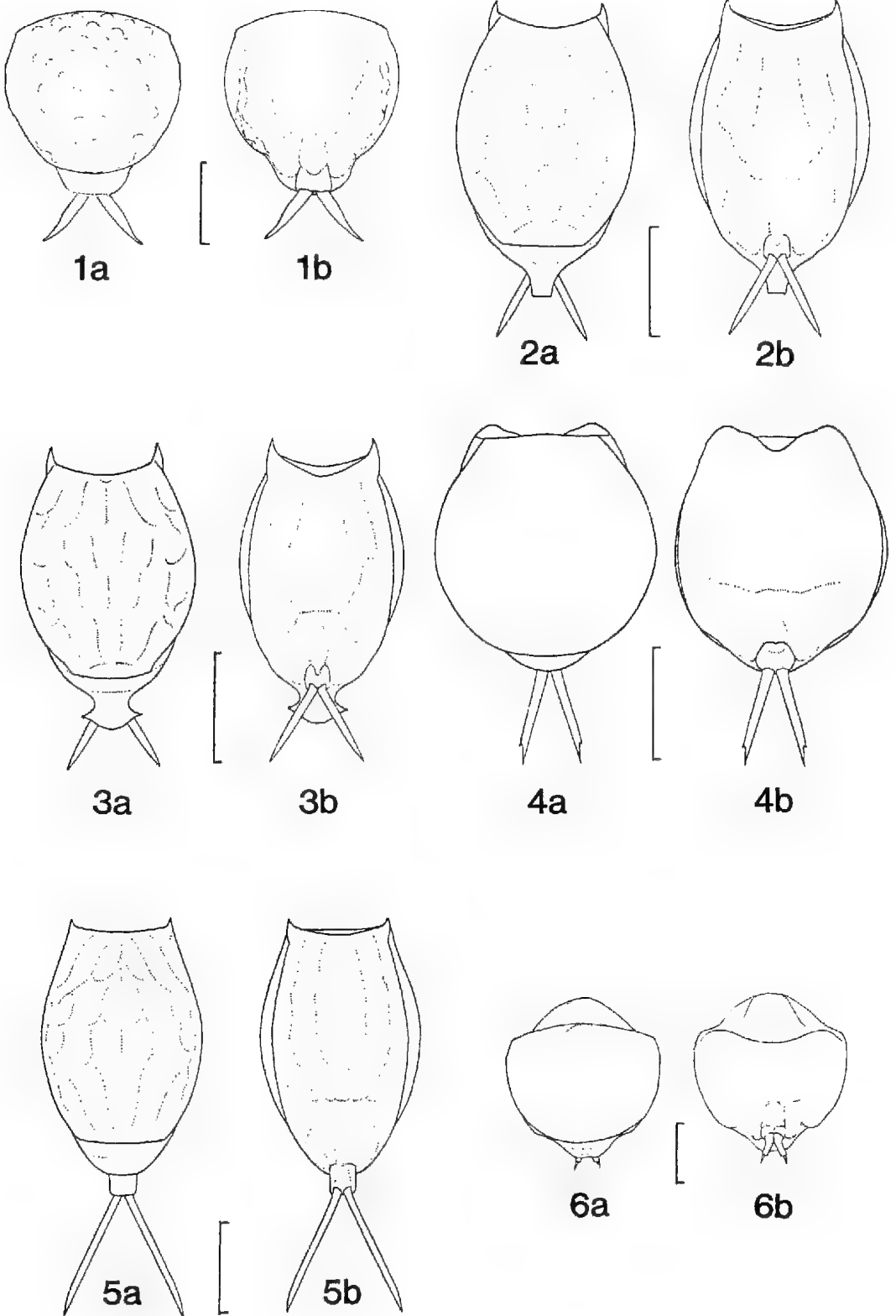
Distyla ludwigi Eckstein, 1883, p. 383, Fig. 26:37.
Lecane ludwigi Harring 1913, p. 61.

Diagnosis: Head aperture margins coincident, concave; two stout cusps at external angles; dorsal plate truncate posteriorly, ornamented with four rows of tessellations to give shingled appearance (Fig. 11:6a); ventral plate with transverse fold and several longitudinal ridges; lateral sulci very deep; posterior segment produced to long, triangular pointed spine; toes long, slender, $\frac{1}{2}$ total length, tapering to acute conical points (no claw).

Dorsal plate 104-121 \times 77-84 μm ; ventral plate to 162 \times to 80 μm ; toes 40-44 μm , subitaneous egg 102 \times 45 μm .

Distribution: Cosmopolitan warm stenotherm.

Fig. 12. 1, *Lecane* sp.; ventral. 2, *L. ludwigi errodes* (Harring); dorsal. 3, *L. luna* (Müller); (a) dorsal; (b) ventral. 4, *L. mira* (Murray); (a) dorsal; (b) ventral. 5, *L. myliacis* Harring & Myers; (a) dorsal; (b) ventral. 6, *L. nana* (Murray); (a) dorsal; (b) ventral. 7, *L. erida* (Murray); (a) dorsal; (b) ventral. Fig. 12: 3-6, after Harring & Myers (1926); 7, after Hauer (1938). Scale lines 50 μm .



Rare: the typical form is known from N.T., Qld. southwest W.A. 12.0-17.0°C; pH 4.3-4.8; 26-98 $\mu\text{S cm}^{-1}$. *L. ludwigi laticaudata* Hauer (1938) occurs in Coongie Lakes, S.Aust. (Shiel unpubl.).

Lecane luna (Müller)

FIG. 12:3

Cercaria luna Müller, 1776, p. 280.

Lecane luna: Nitzsch 1827, p. 68.

Diagnosis: Head aperture margins not coincident: both with deep lunate sinuses, dorsal anteriorly $\frac{3}{4}$ width of ventral; external angles of ventral sinus cusp-like, dorsal sinus angles more blunt; smooth dorsal plate almost circular with broad median anterior hump (Fig. 12:3a), ventral plate slightly narrower with single transverse fold; posterior segment small, rounded, projects slightly beyond dorsal plate; toes $\frac{1}{2}$ total length, terminate in claw with basal spicule.

Dorsal plate 122-163 \times 102-150 μm ; ventral plate 132-177 \times 104-80 μm ; toes 44-64 μm ; claws 8-10 μm . **Distribution:** Cosmopolitan in littoral of fresh-, athalassic saline and estuarine waters. Pancontinental, common. 10.0-27.0°C, pH 4.6-8.4, DO 5.8-10.0 mg l^{-1} , 37-3330 $\mu\text{S cm}^{-1}$, <1-160 NTU. **Literature:** Evans 1951; Koste 1978, 1981; Koste & Shiel 1979; Berzins 1982.

Lecane mira (Murray)

FIG. 12:4

Cathypna mira Murray, 1913a, p. 553, Fig. 22:3

Lecane mira: Harring & Myers 1926, p. 342, Figs 17:5, 6.

Diagnosis: Head aperture margins not coincident: dorsal almost straight, ventral slightly concave; two stout triangular cusps at external angles; dorsal plate indistinctly faceted, with anterior row incomplete; ventral plate with light transverse fold only; lateral sulci deep; posterior segment truncate, projects beyond dorsal plate; second foot segment visible beyond posterior segment; toes $\frac{1}{4}$ total length, terminate in stout claw with basal spicule.

Dorsal plate 108-132 \times 97-130 μm ; ventral plate to 145 \times 100 μm ; toes 50-56 μm ; claws 9-12 μm .

Distribution: Widely distributed in acid (*Sphagnum*) waters. There is an unverified record of *L. mira* from Qld (Berzins 1982). A single individual from L. Mulwala, Vic. has some features of *L. mira*, however as shown by the ventral view (Fig. 12:1), there are several morphological differences, particularly in the posterior plate, foot and toes, which suggest that specific status may be warranted. Further material is necessary for adequate description.

Literature: Koste 1978.

Lecane mylaccis Harring & Myers

FIG. 12:5

Lecane mylaccis Harring & Myers, 1926, p. 359, Figs 25:5, 6.

Diagnosis: Head aperture margins almost coincident: ventral straight, dorsal slightly convex; two minute spines at external angles; dorsal plate smooth, larger than ventral plate; ventral plate with distinct folds (Fig. 12:5b); $>\frac{1}{2}$ second foot segment projects beyond posterior margin; toes inserted ventrally part way along segment rather than at usual distal end; external margins of toes curve in distally to small pointed claws.

Dorsal plate 145 \times 108 μm ; ventral plate 130 \times 82 μm ; anterior margin width 72 μm ; toes 32 μm ; claws 7 μm .

Distribution: North America. Not recorded in our collections. Unconfirmed record from central Vic. **Literature:** Koste 1978; Berzins 1982.

Lecane nana (Murray)

FIG. 12:6

Cathypna nana Murray, 1913a, p. 53, Fig. 14:29a-c.

Lecane nana: Harring 1914, p. 536.

Diagnosis: Anterior margins coincident and convex, without corner spines; dorsal plate smooth, wider than ventral plate, which has several disconnected lines (Fig. 12:6b); posterior segment small, truncate, projects beyond dorsal margin, covers second foot segment; toes straight on inner edges, outer margins taper to point, no claw.

Total length 85-90 μm ; dorsal plate 45-64 \times 44-62 μm ; ventral plate 52-68 \times 52-60 μm ; frontal width 36 μm ; toes 20-30 μm .

Distribution: Cosmopolitan in fresh and brackish water. Rare; Qld, Tas., Vic. 15.5-18.5°C, pH 6.8-7.4, DO to 11.0 mg l^{-1} , 70-565 $\mu\text{S cm}^{-1}$.

Literature: Koste 1978; Shiel & Koste 1979; Green 1981; Berzins 1982.

Lecane nitida (Murray)

FIG. 12:7

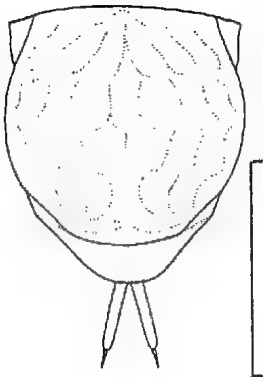
Cathypna nitida Murray, 1913a, p. 347, Fig. 14:24a, b.

Lecane curvicornis Harring & Myers, 1926, p. 321, Fig. 7:1, 2.

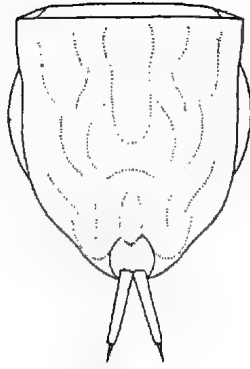
L. curvicornis nitida: Hauer 1938, p. 513, Fig. 37a, b.

Diagnosis: Lorica broadly resembles *L. curvicornis*, however, unlike that species both dorsal and ventral plates are distinctively ornamented; posterior plate also with distinct lines and more rectangular than that of *L. curvicornis*; head aperture margins show

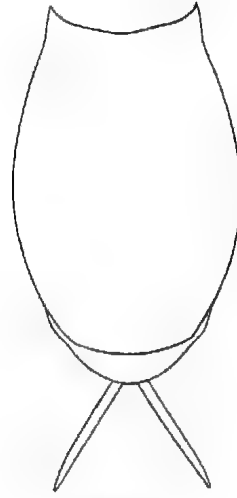
Fig. 13. 1, *Lecane nodosa* Hauer: (a) dorsal; (b) ventral. 2, *L. ohioensis* (Herrick): (a) dorsal; (b) ventral. 3, *L. ohioensis ichthyoura* (Anderson & Shephard): (a) dorsal; (b) ventral. 4, *L. papuana* (Murray): (a) dorsal; (b) ventral. 5, *L. pertica* Harring & Myers: (a) dorsal; (b) ventral. 6, *L. pumila* (Rousselet): (a) dorsal; (b) ventral. Fig. 13: 1, 6, after Hauer (1938), 2-5, after Harring & Myers (1926); 5, after Hauer (1938). Scale lines 50 μm .



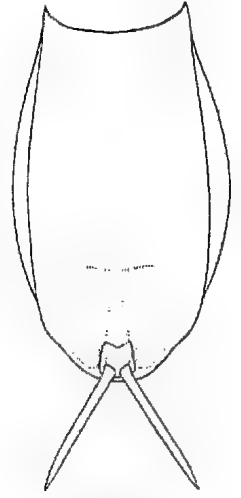
1a



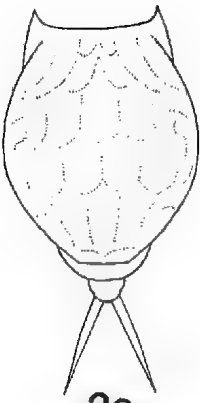
1b



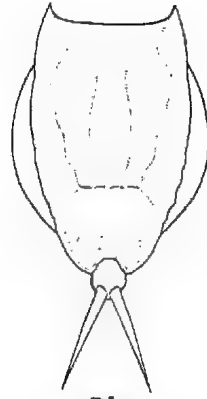
2a



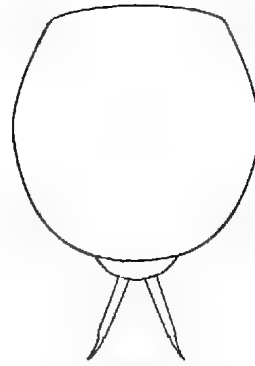
2b



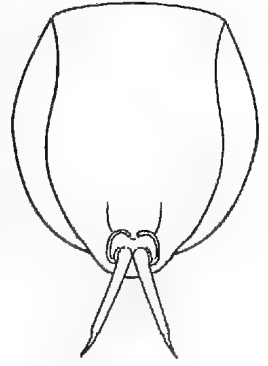
3a



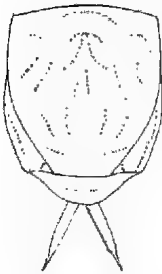
3b



4a



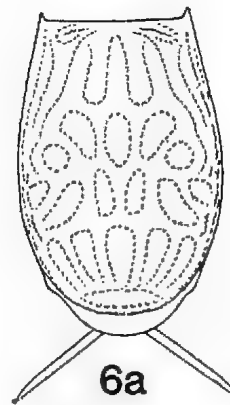
4b



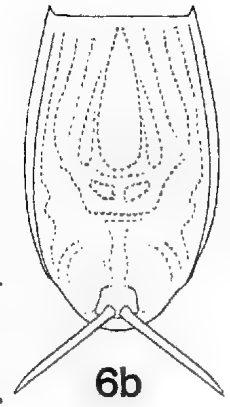
5a



5b



6a



6b

some irregularity of broad V-shape; dorsal plate relatively broader; toes impinge on distal end of second foot segment rather than on ventral surface as in *L. curvicornis*. No measurements are given for *L. nilda* by Harring & Myers (1926) or Koste (1978), however those by Hauer (1938) indicate a larger animal than *L. curvicornis*.

Dorsal plate $127 \times 117 \mu\text{m}$; ventral plate $124 \mu\text{m}$ wide; head aperture $62 \mu\text{m}$; toes $78 \mu\text{m}$; claw $12 \mu\text{m}$. *Distribution*: South America. Single record from Magela Ck., N.T.

Literature: Koste 1981.

Lecane nodosa Hauer

FIG. 13:1

Lecane nodosa Hauer, 1938, p. 520, Fig. 42a, b

Diagnosis: Head aperture margins coincident, convex; no corner spines; dorsal plate wider than long, rounded posteriorly, covered with regular knobby hemispheres (cf. *L. hornemanni*); ventral plate narrower than dorsal, with indistinct lateral margins; no lateral sulci; broad posterior plate covers foot segments; toe stout, broad, parallel-sided for $\frac{1}{3}$ its length, tapering to outward-curved point; no claw.

Total length $87\text{--}120 \mu\text{m}$; dorsal plate $60\text{--}81 \times 67\text{--}82 \mu\text{m}$; ventral plate $70\text{--}90 \times 67\text{--}77 \mu\text{m}$; frontal width $58 \mu\text{m}$; toes $23\text{--}30 \mu\text{m}$.

Distribution: In periphyton, Java, India. Rare: Jabiluka, N.T. and L. Calani, Vic. 24.5°C , pH 6.3, DO 5.8 mg l^{-1} , $59 \mu\text{S cm}^{-1}$.

Comment: The possible synonymy of *L. nodosa* with *L. hornemanni* and *L. nana* was noted by Koste (1978). Protrusion of the second foot segment beyond the lorica margin, non-curving toes and larger overall dimensions in *L. hornemanni* readily separate this taxon. *L. nana* is similar in size and outline, differing apparently only in toe morphology and dorsal lorica ornamentation, which may represent ecotypic variation of a single species.

Literature: Koste 1981; Berzins 1982.

Lecane ohioensis Herrick

FIG. 13:2

Distyla ohioensis Herrick, 1885, p. 54, Fig. 1

Lecane ohioensis Harring 1913, p. 62.

Diagnosis: Head aperture margins concave, almost coincident (ventral slightly shorter); two stout cusps at external angles; dorsal plate ornamented with four prominent rows of tessellations; ventral plate with a few folds and ridges; posterior segment tapers to median, truncate projection extending $\frac{1}{3}$

length of toes; toes parallel-sided, terminate in conical points; no claws.

Dorsal plate $97\text{--}100 \times 78\text{--}93 \mu\text{m}$; ventral plate $114\text{--}146 \times 70 \mu\text{m}$; toes $35\text{--}40 \mu\text{m}$.

Distribution: Cosmopolitan in littoral of freshwaters. Rare: N.T., Qld, S.Aust., Tas. (in moderately saline stock dams, east coast), Vic. $10.2\text{--}29.9^\circ\text{C}$, pH $5.5\text{--}8.1$, $44\text{--}6600 \mu\text{S cm}^{-1}$, alkal. 2.6 mg l^{-1} .

Comment: A variant described from Victoria by Anderson & Shephard (1892), *Distyla ichthyoura* (*Lecane ichthyoura*) (Fig. 13:3) was synonymised with *L. ohioensis* by Koste (1978). The only difference between the two is the fishtail form of the caudal process in the former, which is variable. *L. ohioensis ichthyoura* apparently is a cosmopolitan halophile. Rare: S.Aust., Vic. southwest W.A.

Literature: Koste 1978; Koste & Shiel, 1983.

Lecane papuana (Murray)

FIG. 13:4

Distyla papuana Murray, 1913, p. 551, Fig. 22:2.

Lecane papuana: Harring & Myers 1926, p. 336, Figs 14:3, 4.

Diagnosis: Head aperture margins not coincident; dorsal almost straight, ventral with broad shallow V-shaped sinus with undulate sides, rounded posteriorly; no cusps at external angles, but distinctive rounded lobes of ventral lorica project well beyond dorsal margin; lateral sulci moderately deep; ventral plate slightly narrower than dorsal, with same circular outline; posterior segment rounded, projects slightly; toes $> \frac{1}{4}$ total length, slightly dilated distally before stout claw, which has two basal spicules.

Dorsal plate $92\text{--}120 \times 82\text{--}102 \mu\text{m}$; ventral plate $112\text{--}115 \times 91\text{--}98 \mu\text{m}$; toes $34\text{--}50 \mu\text{m}$; claw $8\text{--}12 \mu\text{m}$.

Distribution: Between macrophytes in tropical and subtropical shallow waters. Rare: N.T., Qld, S.Aust., Vic. $17.0\text{--}29.8^\circ\text{C}$, pH $5.3\text{--}8.2$, DO $6.1\text{--}9.7 \text{ mg l}^{-1}$, $23\text{--}1000 \mu\text{S cm}^{-1}$, $40\text{--}88 \text{ NTU}$, alkal. $1.9\text{--}2.7 \text{ mg l}^{-1}$.

Literature: Koste 1978, 1981.

Lecane pertica Harring & Myers

FIG. 13:5

Lecane pertica Harring & Myers, 1926, p. 340, Fig. 12:1, 2

Diagnosis: Elongate lorica, dorso-ventrally compressed; head aperture margins almost coincident; dorsal straight, ventral slightly concave; two small spines at external angles; dorsal plate truncate posteriorly, indistinctly faceted; ventral

Fig. 14. 1, *Lecane pusilla* Harring: (a) dorsal; (b) ventral. 2, *L. pyrcha* Harring & Myers: (a) dorsal; (b) ventral. 3, *L. rhytida* Harring & Myers: (a) dorsal; (b) ventral. 4, *L. rotundata* (Olofsson): (a) dorsal; (b) ventral. 5, *L. rutineri* Hauer: (a) dorsal; (b) ventral. 6, *L. signifera signifera* (Jennings): (a) dorsal; (b) ventral. Fig. 14: 1-3, 6, after Harring & Myers (1926); 5, after Hauer (1938). Scale lines $50 \mu\text{m}$.

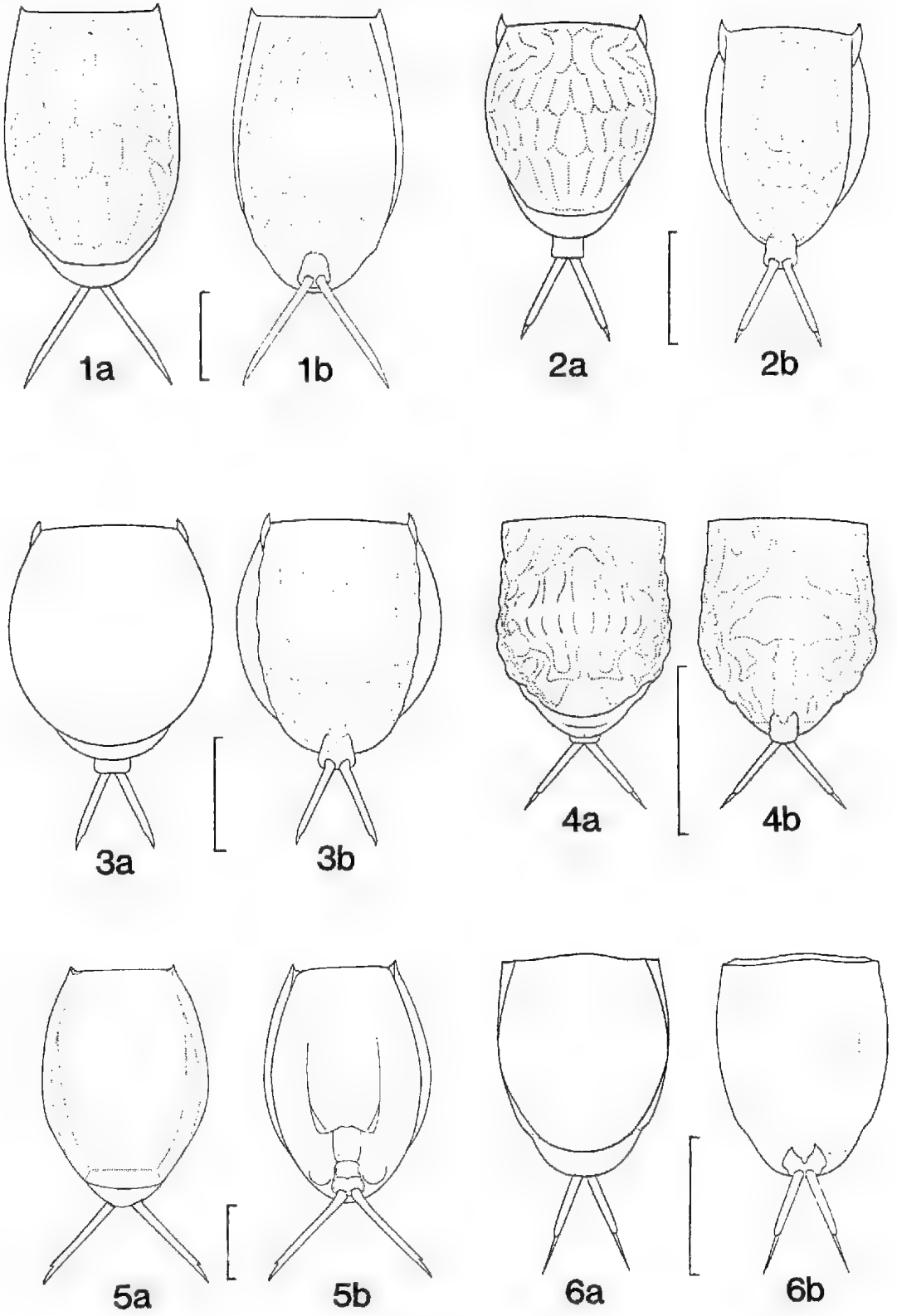


plate clearly marked (Fig. 13:5b); deep lateral sulci; semicircular posterior segment projects well beyond dorsal plate; second foot segment projects almost all its length beyond posterior segment; toes very long, $\frac{1}{2}$ total length, straight, parallel-sided, terminate in acute points; no claws.

Total length to 260 μm ; dorsal plate 97-140 \times 66-100 μm ; ventral plate 115-160 \times 60-88 μm ; anterior margin 46-64 μm ; toes 60-85 μm .

Distribution: North and South America, Indonesia. Acidophil. Rare: billabongs of Magela Creek, N.T. 24.5-29.9°C, pH 5.5-6.3, DO 5.5-5.8 mg l⁻¹, 44-59 $\mu\text{S cm}^{-1}$, alkal. 2.6 mg l⁻¹.

Literature: Koste 1978, 1981.

Lecane pumila (Rousselet)

FIG. 13:6

Notommata pumila Rousselet, in Murray, 1906, p. 183, Fig. 6:25.

Lecane pumila: Hauer 1936, p. 154, Figs 1-3.

Diagnosis: Loric flexible, although form constant; lateral sulci absent; toes extremely short; claw points curved backwards.

Total length 75-170 μm ; dorsal plate 60-75 \times 90-140 μm ; ventral plate 80-110 μm ; toes 3-5 μm .

Distribution: Europe, Indonesia, N.America, in moss in standing and flowing water. Single record from L. St Clair, Tasmania, 17.0°C, pH 7.3, 21.1 $\mu\text{S cm}^{-1}$.

Literature: Koste & Shiel 1986a.

Lecane pusilla Harring

FIG. 14:1

Lecane pusilla Harring, 1914, p. 541, Fig. 20:4-6.

Diagnosis: Head aperture margins straight, dorsal projects slightly beyond ventral; no corner spines; dorsal plate distinctly faceted, ventral plate less conspicuously patterned; lateral sulci deep; posterior segment rounded, projecting well beyond dorsal plate margin; toes long, slender; $> \frac{1}{4}$ total length, tapering to long, recurved, acute claw.

Total length to 75 μm ; dorsal plate 54 \times 52 μm ; ventral plate 60 \times 45 μm ; anterior margin 50 μm ; toes 20-26 μm ; claws 5 μm .

Distribution: Central America, E. Europe, Iran. Rare: Bromfield Swamp, Qld, Vic. No ecological information available.

Literature: Koste 1978; Green 1981; Berzins 1982.

Lecane pyrroha Harring & Myers

FIG. 14:2

Lecane pyrroha Harring & Myers, 1926, p. 331, Fig. 12:3-6.

Diagnosis: Head aperture margins coincident, concave; two stout triangular cusps at external angles; no patterning of dorsal or ventral loric; posterior segment projects slightly beyond dorsal plate; toes long slender, $\frac{1}{4}$ total length, without claws.

Total length to 280 μm ; dorsal plate 193 \times 145 μm ; ventral plate 210 \times 125 μm ; anterior margin 80 μm ; toes 75 μm .

Distribution: North America in soft acid waters. Not recorded in this study. Single report from Victoria by Berzins (1982) needs confirmation.

Lecane rhytida Harring & Myers

FIG. 14:3

Lecane rhytida Harring & Myers, 1926, p. 346, Fig. 20:3, 4.

Diagnosis: Head aperture margins coincident, slightly concave; two stout triangular cusps at external angles, dorsal plate distinctly faceted, ventral with prominent markings (Fig. 14:3b); lateral sulci indistinct; posterior segment small, projects slightly beyond dorsal plate; second foot segment robust, projects $\frac{1}{2}$ its length beyond posterior margin; toes long, slender; $\frac{1}{4}$ total length, tapering to very long acute points.

Total length to 126 μm ; dorsal plate 80 \times 69 μm ; ventral plate 87 \times 65 μm ; anterior margin 42 μm ; toes 39 μm .

Distribution: North America, soft acid water. Not recorded in this study. Single report from Victoria by Berzins (1982) needs confirmation.

Lecane rotundata (Olofsson)

FIG. 14:4

Cathypna rotundata Olofsson, 1918, p. 593, Fig. 53.

Lecane rotundata: Remane 1932, p. 110.

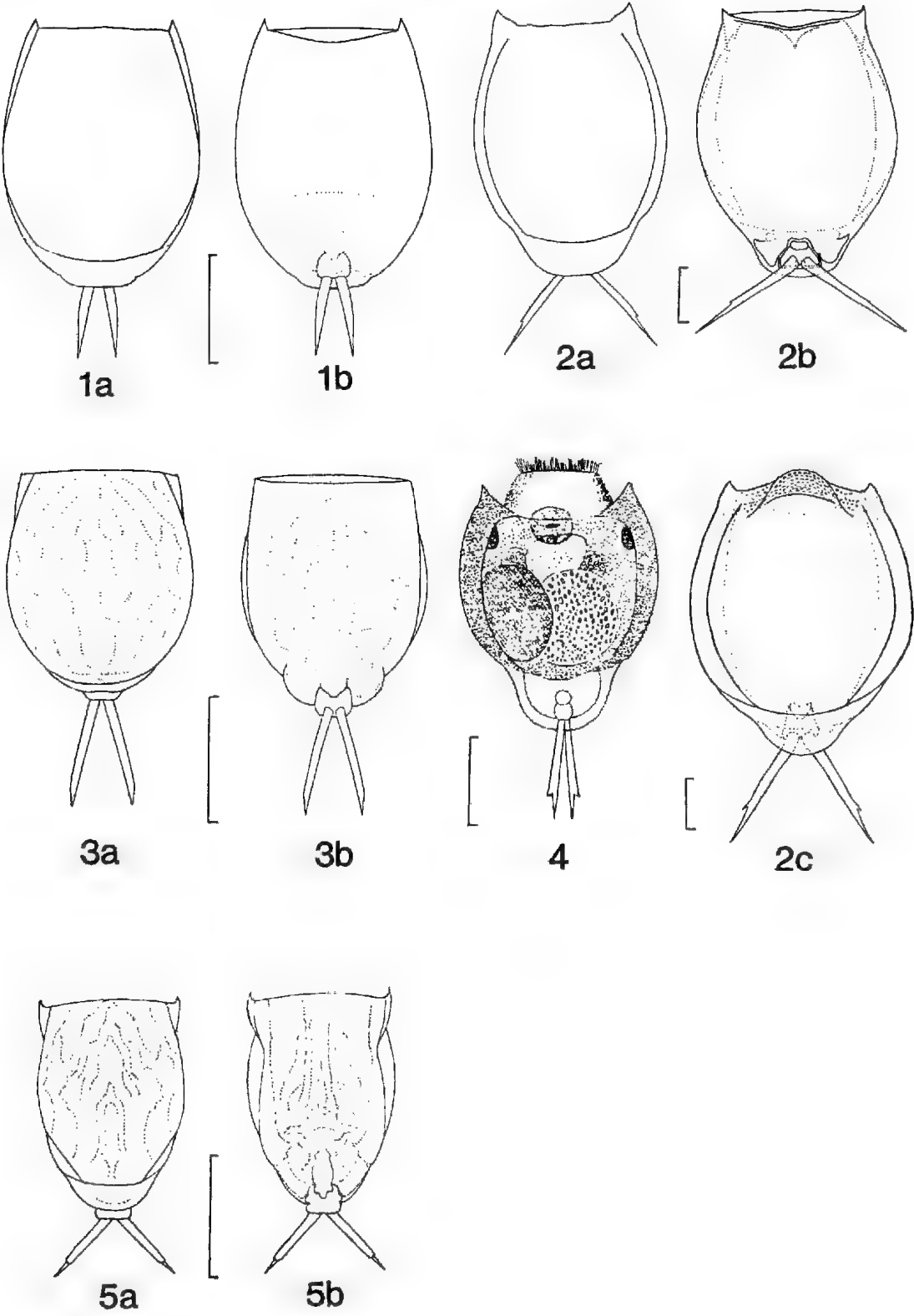
?*Lecane latissima* Yamamoto, 1955, p. 33, Fig. 1a, b.

Diagnosis: Head aperture margins coincident, convex; frontal spines absent; dorsal plate smooth, almost circular, much wider than ventral plate; lateral sulci absent; posterior plate semicircular, projects beyond dorsal margin; toes long; claws short, pointed.

Dorsal plate 90 \times 106-112 μm ; ventral plate 103-113 \times <103 μm ; toes 37-39 μm ; claws 6 μm .

Distribution: Northern Europe, Japan. Only known

Fig. 15. 1, *L. signifera ploenensis* (Voigt): (a) dorsal; (b) ventral. 2, *L. stichaea* Harring: (a) dorsal; (b) ventral. 3, *L. stichaea intraspinata* (Olofsson): (a) dorsal; (b) ventral. 4, *L. subtilis* Harring & Myers: (a) dorsal; (b) ventral. 5, *L. tasmaniensis* Koste & Shiel: (a) dorsal; (b) ventral. 6, *L. tenuiseta* Harring: (a) dorsal; (b) ventral. Fig. 15: 1-4, 6, after Harring & Myers (1926); 5, after Koste *et al.* (1983). Scale lines 50 μm .



from L. Pedder, Tas, 13.5-14.3°C; pH 4.6-6.1; 30.0-38.7 $\mu\text{S cm}^{-1}$.

Literature: Koste 1978; Koste *et al.* 1988.

Lecane rutneri Hauer

FIG. 14:5

Lecane rutneri Hauer, 1938, p. 523, Fig. 46a, b.

Diagnosis: Lorica outline rectangular; head aperture margins coincident, weakly convex, dorsal margin wider than ventral; corner spines absent; dorsal plate narrower than ventral, tapers to truncate posterior margin; both surfaces weakly ornamented as figured; lateral sulci absent; posterior segment bilaterally constricted, rounded posteriorly; second foot segment not projecting beyond caudal margin; toes $\frac{1}{3}$ body length, straight on inner margin, tapering on outer margin to short, acute claw.

Dorsal plate 53 \times 48 μm ; ventral plate 62 \times 50 μm ; anterior margins 46 μm (dorsal), 40 μm (ventral); toes 17-19 μm ; claws 6 μm .

Distribution: Indonesia. Single record, L. Boort, Vic. 20.0°C; pH 7.4; DO 8.8 mg l⁻¹, 1500 $\mu\text{S cm}^{-1}$.

Literature: Koste 1978.

Lecane signifera (Jennings)

FIG. 14:6

Distyla signifera Jennings, 1896, p. 92, Figs 1, 2.

Lecane signifera: Harring 1913, p. 62.

Diagnosis: Head aperture margins coincident, straight; two small cusplike spines at external angles; unusual lorica ornamentation: beadlike hemispheres closely spaced on slopes of elevated ridges; shallow lateral sulci; posterior segment projects slightly beyond dorsal plate; toes $\frac{1}{3}$ total length, ending in acute points without claws.

Dorsal plate 124-135 \times 90-96 μm ; ventral plate 136-148 \times 82-88 μm ; toes 52-60 μm .

Distribution: Cosmopolitan, possibly acidophile. Rare; N.T., Qld, Tas., Vic. 20.0°C; pH 7.4; DO 8.8 mg l⁻¹, 1500 $\mu\text{S cm}^{-1}$.

Comment: A subspecies, *Lecane signifera ploensis* (Voigt 1902) (Fig. 15:1) also known from N.S.W., N.T., Qld. It has larger cusps at the external angles than *L. signifera*, and may be larger in some dimensions, although probably subject to ecotypic variation.

Dorsal plate 80-185 \times 66-112 μm ; ventral plate 90-185 \times 55-185 μm ; toes 35-86 μm .

Literature: Koste 1978, 1981; Shiel & Koste 1979.

Lecane stichaea Harring

FIG. 15:2

Lecane stichaea Harring, 1913, p. 397, Fig. 35:4-6.

Diagnosis: Head aperture margins coincident, slightly convex; two stout cusps at external angles; intricate surface markings on both dorsal and ventral plates as figured; lateral sulci shallow; ventral plate parallel-side, considerably narrower than dorsal; posterior segment projects well beyond truncate dorsal plate; second foot segment extends $> \frac{1}{2}$ its length beyond posterior margin; toes $> \frac{1}{4}$ total length, ending in acute claw without basal spicule.

Dorsal plate 85-92 \times 69-76 μm ; ventral plate 75-97 \times to 75 μm ; toes 27-39 μm ; claws 5.7 μm .

Distribution: Cosmopolitan in standing waters, springs. Rare: three records, all flowing waters; Magela Ck, N.T., R. Murray, S. Aust. and Macquarie R., Tas. *L. stichaea intrasinuata* (Olofsson 1917) (Fig. 15:3) also occurs in the Magela Ck region. It may be difficult to distinguish from *L. stichaea*, however the dorsal lorica generally is smooth or weakly sculptured, and most dimensions are larger.

Dorsal plate 61-105 \times 78-85 μm ; ventral plate 63-110 \times 41-72 μm ; toes 24-45 μm ; claws 5-7 μm .

Literature: Koste 1978.

Lecane subtilis Harring & Myers

FIG. 15:4

Lecane subtilis, Harring & Myers, 1926, p. 370, Fig. 30:5, 6.

Diagnosis: Anterior lorica almost rectangular; head aperture margins slightly convex, coincident; no frontal spines; very distinctive ornamentation of both surfaces as figured; dorsal plate rounded posteriorly, same width as ventral plate, slightly shorter; lateral sulci indistinct; second foot segment projects slightly; toes ca. $\frac{1}{4}$ total length with long slender claw.

Dorsal plate 54-70 \times 50-60 μm , ventral plate 60-75 \times 50-55 μm , anterior width 56 μm , toes 25-32 μm , claws 5-8 μm .

Distribution: Probably cosmopolitan. Not recorded in this study. Unconfirmed report from Sunbury, Victoria.

Literature: Koste 1978; Bervins 1982.

Lecane tasmaniensis Shiel & Koste

FIG. 15:5

Lecane tasmaniensis Shiel & Koste, 1985, pp. 7-8, Fig. 3.

Diagnosis: Head aperture margins straight,

Fig. 16. 1, *Lecane tuberosa* Harring & Myers: (a) dorsal; (b) ventral. 2, *L. unguolata* (Gosse): (a) dorsal; (b) ventral; (c) *L. unguolata australiensis* Koste, dorsal; 3, *L. venusta* Harring & Myers: (a) dorsal; (b) ventral. 4, *L. spenceri* (Shephard), ventral. Fig. 16: 1, 2a, 3, after Harring & Myers (1926); 2b, c, after Koste (1979). 4, after Anderson & Shephard (1892). Scale lines 50 μm .

coincident; prominent frontal cusps; smooth dorsal plate wider than ventral plate, slightly truncate posteriorly; ventral plate with transverse fold over first foot joint, with two longitudinal lines running anteriorly; toes $< \frac{1}{2}$ body length, parallel-sided to short; claws with basal spicules.

Total length 155-158 μm , dorsal plate to 115 \times 86 μm , ventral plate to 126 \times 79 μm , anterior margin 58 μm , toes 61 μm , claws 10-12 μm .

Distribution: Apparently endemic to Tasmania (west coast and Tasman Peninsula), 10-19.0°C, pH 3.1-5.8, 26-334 $\mu\text{S cm}^{-1}$.

Lecane tenuiseta Harring

FIG. 15:6

Lecane tenuiseta Harring, 1914, p. 543, Fig. 22:1-3.

Diagnosis: Head aperture margins parallel, slightly convex; dorsal plate smooth, rounded posteriorly; ventral plate with series of ridges; lateral sulci shallow; posterior segment broad, rounded, protrudes beyond dorsal plate; second foot segment not protruding; toes long, slender, ca. $\frac{1}{2}$ total length, terminating in extremely long spinelike claw.

Dorsal plate 64-78 \times 56 μm , ventral plate 57-83 \times 56 μm , toes 20-33 μm , claws 13-18 μm .

Distribution: Cosmopolitan, eurytopic. Two records, N.T., W.A. 25.0°C, pH 5.9, DO 2.2 mg l^{-1} , 29 $\mu\text{S cm}^{-1}$.

Lecane tudicola Harring & Myers

FIG. 16:1

Lecane tudicola Harring & Myers, 1926, p. 328, Fig. 11:1, 2.

Diagnosis: Head aperture margins not coincident; dorsal straight, ventral with shallow V-shaped sinus; two small cusps at external angles; smooth dorsal plate narrower than ventral both anteriorly and posteriorly, similar width medially; ventral plate smooth; lateral sulci shallow; posterior plate broad, rounded, with two lateral indentations, projects beyond dorsal plate; second foot segment does not reach lorica rim; toes ca. $\frac{1}{4}$ total length, taper to acute points, no claws.

Dorsal plate 105-120 \times 85-104 μm , ventral plate 110-140 μm , anterior width 58-96 μm , toes 37-48 μm .

Distribution: Asia, N. and S. America. Unconfirmed record from Victoria.

Literature: Koste 1978; Berzins 1982.

Lecane unguolata unguolata (Gosse)

FIG. 16:2a, b

Cathypna unguolata Gosse, 1887, p. 361, Fig. 8:1

Lecane unguolata: Harring 1913, p. 62.

Diagnosis: Head aperture margins not coincident; dorsal almost straight, ventral slightly concave; two large triangular cusps at external angles; smooth

dorsal plate smaller than ventral, with indistinct anterior margin (Fig. 16:2a); ventral plate with single indistinct transverse fold; lateral sulci deep; posterior segment broad, covers foot; toes $> \frac{1}{2}$ total length, end in long stout claw with basal spicule.

Dorsal plate 140-220 \times 138-180 μm , ventral plate 185-255 \times 139-195 μm , toes 73-120 μm , claws 20-45 μm .

Distribution: Cosmopolitan. Rare. N.T., Qld. 24.5°C, pH 5.4-6.3, DO 4.8-6.2, 23-59 $\mu\text{S cm}^{-1}$, alkal, 2.7-4.1 mg l^{-1} .

Comment: A variant, at present considered a subspecies (*Lecane unguolata australiensis* Koste, 1979) (Fig. 15:2c) is known from Magela Ck, N.T. and Goulburn R., Vic. billabongs. It has a distinctive median dome on the dorsal anterior lorica margin, and is considerably larger than *L. unguolata*.

Dorsal plate 230-240 \times 184-200 μm , ventral plate 268-280 \times 216-240 μm , toes 120-130 μm , claws 20-45 μm .

Literature: Koste 1978, 1979, 1981.

Lecane venusta Harring & Myers

FIG. 16:3

Lecane venusta Harring & Myers, 1926, p. 328, Fig. 27.

Diagnosis: Head aperture margins not coincident; dorsal slightly convex, ventral nearly straight; no corner spines; both surfaces with complex ornamentation as figured; posterior segment broadly rounded, projects beyond dorsal plate; second foot segment visible beyond posterior segment; toes long and slender, incurved to acute points; no claws.

Dorsal plate 86 \times 75 μm , ventral plate 84 \times 70 μm , anterior margins 62 μm , toes 42 μm .

Distribution: N. America, U.S.S.R. Rare. Not recorded in this study. Unconfirmed record from Victoria.

Literature: Koste 1978; Berzins 1982.

Incertae sedis

A lecanid resembling *L. luna* was described by Anderson & Shephard (1892) from Brighton, Vic., but 'with some hesitation regarded as new.' It was not named, and the figure (redrawn in Fig. 16:4) of doubtful quality. Subsequently, Shephard (1892) gave a brief redescription and named the rotifer *Cathypna* (= *Lecane*) *spenceri*, Harring (1913) accepted *L. spenceri*, but in view of the lack of taxonomically accurate figures we must regard it as *incertae sedis*, even though the description suggests it may be a valid species.

The original description is reproduced below, and *L. spenceri* is included in the *Lecane* key for ready identification should it be encountered again. It is

notable that other taxa described as new by Anderson & Shephard (1892) and Shephard (1911) (e.g. *Brachionus dichotomus*, *B. tyrannus*), but synonymised with northern hemisphere taxa by later reviewers, subsequently were validated as distinctive Australian endemics (see Koste & Shlei 1987b).

Lecane spenceri Shephard

FIG. 16:4

Cathypna cf. *luna* Anderson & Shephard, 1892, p. 77, Fig. 12:4.

Cathypna spenceri Shephard, 1892, p. 13.

Lecane spenceri: Harring, 1913, p. 62.

Diagnosis: Resembles *L. luna*; the points of difference are ... in the lorica being broader anteriorly and the dorsal occipital edge more deeply excavated, the posterior possessing more of a lobed character, having a decided inward curve on either side and a rounded termination overhanging the toes; the most marked departure being in the setting of the claws, which, instead of tapering from the shoulder to the end, are recessed so as to form a recessed barb; the surface of the lorica was also stippled (Shephard 1892).

Assuming Shephard's figure is drawn to scale, the given length (1/130" or 192 µm) suggests that the approximate measurements of this lecanid are: dorsal plate 111×109 µm, ventral plate 144×109 µm,

anterior width 83 µm, toes 43 µm, claws 13 µm, i.e. comparable in size to *L. luna*.

Distribution: Recorded from Brighton, Vic. No other details given.

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GROWTH AND MORTALITY IN A LIGHTLY FISHED POPULATION OF GARFISH (*HYPORHAMPHUS MELANOCHIR*), IN BAIRD BAY, SOUTH AUSTRALIA.

BY G. K. JONES*

Summary

The age composition, natural mortality and growth rates of garfish *Hyporhamphus melanochir*, were investigated in Baird Bay, a shallow embayment in South Australia which has been closed to commercial and recreational netting for a number of years. Sampling was by beach seine and gill nets of various mesh sizes over four sampling periods in 1984/85. Otoliths were used to estimate Von Bertalanffy growth parameters and the growth equations for male and female fish were $L(t) = 36.7 (1 - e^{-0.51(t-0.12)})$ and $L(t) = 38.7 (1 - e^{-0.54(t-0.3)})$ respectively. The instantaneous rates of natural mortality were estimated by two methods: the slope of the catch curves determined from the age composition data (0.53 for males and 0.36 for females) and using the estimated growth parameters, mean environmental temperature and Pauly's (1981) equation (0.57 for males and 0.56 for females). The results are discussed in relation to fishing strategies for this species and the use of the population in Baird Bay to model the garfish fishery in other parts of State waters.

KEY WORDS: Growth, natural mortality, garfish, *Hyporhamphus melanochir*, fisheries biology.

GROWTH AND MORTALITY IN A LIGHTLY FISHERD POPULATION OF GARFISH (*HYPORHAMPHUS MELANOCHIR*), IN BAIRD BAY, SOUTH AUSTRALIA.

by G. K. JONES*

Summary

JONES, G. K. (1990) Growth and mortality in a lightly fished population of garfish (*Hyporhamphus melanochir*) in Baird Bay, South Australia. *Trans. R. Soc. S. Aust.*, 114(1), 37-45, 11 May, 1990.

The age composition, natural mortality and growth rates of garfish *Hyporhamphus melanochir*, were investigated in Baird Bay, a shallow embayment in South Australia which has been closed to commercial and recreational netting for a number of years. Sampling was by beach seine and gill nets of various mesh sizes over four sampling periods in 1984/85. Otoliths were used to estimate Von Bertalanffy growth parameters and the growth equations for male and female fish were $L(t) = 36.7 (1 - e^{-(0.51 \pm 0.12)t})$ and $L(t) = 38.7 (1 - e^{-(0.54 \pm 0.31)t})$ respectively. The instantaneous rates of natural mortality were estimated by two methods: the slope of the catch curves determined from the age composition data (0.53 for males and 0.36 for females) and using the estimated growth parameters, mean environmental temperature and Pauly's (1981) equation (0.57 for males and 0.56 for females). The results are discussed in relation to fishing strategies for this species and the use of the population in Baird Bay to model the garfish fishery in other parts of State waters.

KEY WORDS. Growth, natural mortality, garfish, *Hyporhamphus melanochir*, fisheries biology.

Introduction

Garfish (*Hyporhamphus melanochir*) is a commercially (Ling 1958; Jones 1979¹) and recreationally (Jones, 1981, 1983) important species taken in inshore waters of South Australia. In 1987/88 the commercial catch was 433 tonnes and this was mainly taken in Spencer Gulf and Gulf St Vincent (Fig. 1). Although the catch by recreational fishermen is not known, a large proportion of the total catch is taken by commercial net fishermen using three centimetre mesh ring nets. Some areas of the inshore waters of the State have been closed to netting for a number of years, but hand dab netting and handlining for the species has continued. Baird Bay, S. Aust. (33°06'S, 134°18'E) (Fig. 2) was partially closed to netting since 1950 and fully closed in 1979; however, fishing by handline and dabnetting is permitted.

The Bay has an average depth of two metres and a limestone/sand substrate, the southern areas dominated by stands of the seagrasses *Posidonia australis* and *Zostera mucronata*, and the northern areas by *Z. mucronata* and the brown alga *Hormosira banksii*. The bay totalling 3,800 hectares has a narrow entrance to the Great Australian Bight at its southern end. Because of the high surface area to depth ratio and the small entrance, waters of the Bay are subject to relatively large ranges in water temperature and salinity, dependent on the season

and location. High temperatures (21 - 23°C) and salinities (37.6 - 50.3‰) occur in the northern regions during the months October - March, and in the southern part, conditions are close to those of the Great Australian Bight (19 - 23°C, 37.0 - 37.8‰).

Until 1979, a small fishery for garfish existed in this Bay, producing annual catches of up to 4000 kgs. In 1950, the bay was partially closed to netting, with the exception of Dunn's Bay (Fig. 2); however, the fishery continued in the latter area until 1979 when the whole of Baird Bay was closed to netting. Since then, catches of only 1 - 10 kg by handline have been reported. Recreational catches are also believed to be of the same magnitude. With the large decline in fishing effort and landings in this Bay, most of the mortality of garfish can now be considered to be due to natural causes.

The natural mortality rate (M) is one of a number of parameters used to model the dynamics of fish populations. For most fished populations, it is often difficult to separate natural mortality from that of fishing mortality (F), if fishing effort or catches are not known (Gulland 1983). However, in the case of populations which are subject to little or no fishing, information on the age composition of the population can be used to determine the natural mortality rate by estimating the rate of decline in the number of fish in consecutive age groups (Hughes 1974; Vuoren 1977). This method of estimating the natural mortality rate on the population of garfish in Baird Bay is used in this paper, as well as another independent method (Pauly 1981). The second method assumes that the size of the fish (length or weight), growth rate of the fish (expressed as the growth constant, K) and

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¹ Jones, G.K. (1979) Biological investigations on the marine scale fishery in South Australia. S.A. Dept. Ag. & Fish; Unpubl. Rep. 72 pp.

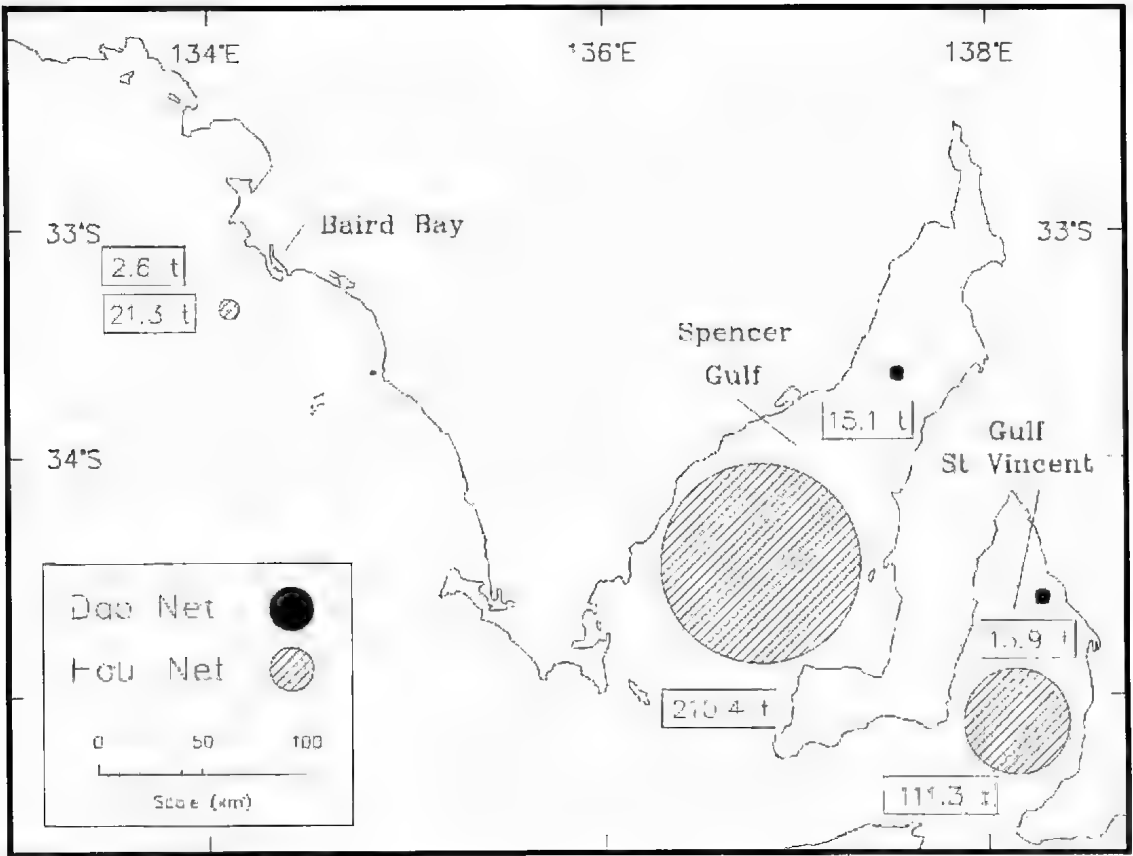


Fig. 1. Annual commercial catches (kg, live wt) of garfish in west coast, Spencer Gulf and Gulf St Vincent in 1987/88, showing the relative importance of hauling and dab netting in each area.

the mean environmental temperature significantly affect the natural mortality rate of the fish. A relationship in the form of a multiple linear regression has been determined between these factors and the known natural mortality rates for 175 fish stocks.

There are two assumptions underlying the estimation of natural mortality rate for any species of fish. These are that: 1) the entire stock is investigated, i.e. there is no emigration nor immigration, and 2) the sampling method representatively samples the whole population. Although the natural mortality rate is stock specific, the parameter can be used as a guide for other heavily fished populations of garfish in State waters, as an aid in determining management options.

In addition to the estimation of natural mortality, knowledge of the growth parameters for this species is beneficial because of their importance in determining of the Beverton – Holt yield per recruit relationship and other population dynamic models. Ling (1958), who studied the growth and spawning cycle of garfish in S. Aust. waters, included data

on growth from a number of areas in the State. These are compared with the present results for Baird Bay. Growth was estimated from the aging of otoliths, a technique validated by Ling (1958) from the seasonal change in the proportion of hyaline rings at the edge of the otolith.

Materials and Methods

Garfish were sampled four times in northern and southern Baird Bay between July 1984 and March 1985 (Fig. 2), using a beach seine (120 metres length, 3cm mesh wings and 0.5cm mesh centre bunt) and four floating gill nets (each of 50 metres length, 2 metres depth and mesh sizes 3.0, 3.8, 4.8 and 5.0cm respectively) in each area. Beach seine shots were undertaken during daylight hours at low tide, and gill nets shot at dusk, parallel to the tidal current and hauled at dawn the following day.

Garfish were measured from the tip of the upper jaw to the extremity of the caudal fin, sexed, gonad stages recorded and pairs of otoliths extracted and placed in paper envelopes for subsequent aging.

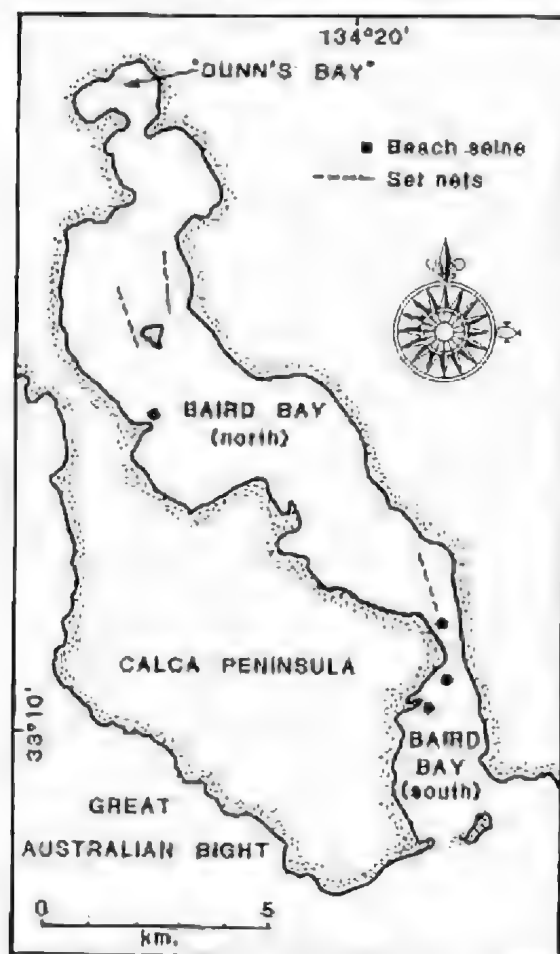


Fig. 2. Location of Baird Bay, South Australia and the stations where beach seining and gill netting were undertaken.

In the laboratory, one of each pair of otoliths was cleaned in a weak solution of detergent and water, broken in half, and one of the halves ground smooth with an electric grinder (5,000 revs./min.). The otolith was then lightly burnt using a medical spirit burner for 10 - 15 secs, and mounted in plasticine. The ground edge was painted with a small drop of glycerine and observed under a 25 × binocular microscope. Burning blackened the hyaline zones (or annuli) and these were counted.

Although the age composition of male and female garfish was determined for each sampling period, there was little difference between the four sampling periods and the two areas and so the data were therefore combined. To determine growth curves for the two sexes, mean lengths at age were calculated and the data incorporated in "FISHPARM" program (Saila, Recksieck & Prager 1988) which gave the von Bertalanffy growth

parameters (k , L_{∞} , & t_0). Catch curves for sexes separately and combined were calculated by plotting the \log_e of the total numbers of fish caught in the gill nets for each age class of the captured fish. The slope of the regression is the mortality rate (Gulland 1983). Lines of best fit and their standard errors were calculated using a linear regression software package (Hill pers comm).

Natural mortality rate (M) was also calculated by using the estimated growth parameters, the average water temperature (20°C) in Baird Bay, and the following equation developed by Pauly (1981):

$$\log_{10} M = -0.0066 - 0.279 \log_{10} L_{\infty} + 0.6543 \log_{10} K + 0.4634 \log_{10} T \quad (1)$$

where M = natural mortality rate,

L_{∞} = von Bertalanffy theoretical maximum length,

K = von Bertalanffy growth constant,

T = mean environmental temperature.

Results

Size composition of garfish. The size composition of garfish taken by beach seine and different sized gill nets (Fig. 3), indicate major differences for the type of net used. The relatively small fish taken in the beach seines might have been related to differences in the areas sampled, or differences in the sampling time (day v's night sampling), or a combination of both factors. Data for the gill nets show that they were size selective, with major differences between 3.0, 3.8 and 4.8 cm mesh nets (Fig. 3). There was little difference in the selectivity between the 4.8 and 5.0 cm mesh nets; but this was possibly because no larger garfish were available in the sampling areas.

Seasonal differences in catch rate and size composition of garfish and their spawning time. As the same level of fishing effort was expended during each sampling period, the results for the four mesh sizes were combined. Catch rates (Fig. 4) were greatest in Oct. 1984 with the main size group being 30 - 39 cm S.L. The catch rates for smaller fish (20 - 25 cm) were also the greatest during this period.

At this time, also, both male and female fish greater than 28 cm length were found to be in spawning condition, with eggs coating the meshes of the gill nets as they were being hauled. For fish in the length range of 20 - 25 cm, the gonads were found in an advanced stage of development, with eggs visible and testes coloured white, but no evidence of sperm discharge.

During January, the fish sampled at lengths 23 - 27 cm were found in running ripe condition, however, all those greater than 27 cm were in spent condition. During the other sampling periods, (July

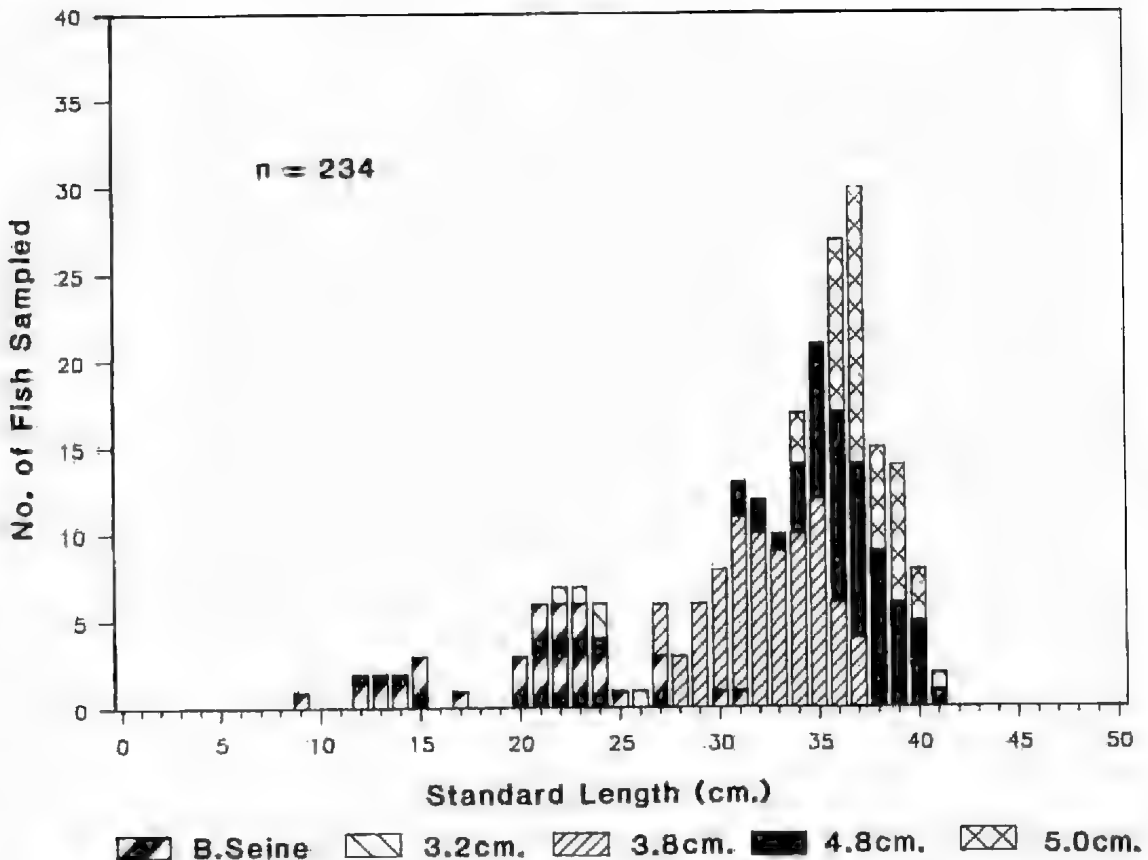


Fig. 3. Cumulative size composition of garfish in Baird Bay according to fishing method and mesh size of gill nets.

1984 and March 1985), the gonads of all fish greater than 20 cm were threadlike and in resting condition.

Relationship between sex ratio and fish length. Immature fish were found at lengths ranging from 9 - 20 cm, and at greater than the length of 20 cm both sexes were able to be determined (Fig. 5). At lengths 20 - 26 cm females predominated in the catches, whereas at lengths greater than 27 cm males were more numerous than females.

Growth rates and growth curves. Otoliths from 210 fish were examined for aging, with a success rate of 93.4%. Table 1 shows the calculated growth parameters and standard errors using the "FISHPARM" software package. The calculated mean lengths at age and those predicted from the von Bertalanffy growth parameters are shown in Fig. 6 and show good agreement.

The "FISHPARM" software package was used to obtain growth parameters on *H. melanochir* from other areas of the State, using raw data of Ling (1958). These data show similarities between the two studies, for one and two year old fish, but there were higher growth rates for older fish from this study. This was true for both sexes (Fig. 7), where both

the present data and that of Ling (1958) show that growth rates for female *H. melanochir* were higher than for males.

Estimation of natural mortality rate. The log_e of the number of fish at each age group was plotted for both sexes individually and combined (Fig. 8). Full recruitment into the sampling year was assumed to occur at that age group which had the peak in abundance. For both sexes this occurred at the age of four years.

The instantaneous rates of natural mortality were the slopes of the regression equations for the respective sets of data for fish of four years and over and these were $0.53 (\pm 0.13)$, $0.36 (\pm 0.10)$ and $0.55 (\pm 0.13)$. These were converted to annual survival rates of 50.7%, 65.7% and 48.2%, using the formula $S = e^{-x}$, where x = instantaneous mortality rate.

Using the growth parameters determined (Table 1) and a mean water temperature of 20°C and equation (1), the estimated of M for male and female *H. melanochir* were 0.93 and 0.95 respectively. Pauly (1981) mentions that for some species which show schooling behaviour, (e.g.

clupeids), a conversion factor of 0.6 should be used to convert M to a more likely estimate. This would give for *H. melanochir* (also an intensively schooling species), new estimates of 0.56 for males and 0.57 for females.

Discussion

This importance of Baird Bay to garfish is probably related to the extensive stands of seagrass in the Bay, which are used for feeding (Klumpp & Nichols 1983), and spawning (Ling 1958). The observations on the reproductive status are similar to those for other parts of the State (Ling 1958), in which spawning took place in October and the size at first maturity was at 21–22 cm standard length. Also, at this time, catch rates of all sizes of fish were higher than at other times of the year, suggesting an increase in catchability due to spawning aggregations.

The only published data on the growth parameters of other species of the same family (Memirhamphidae) are for *H. brasiliensis*. Pauly (1984) estimated the parameters for the latter species at $L_{\infty} = 32.6$ cm, $k = 0.581$ and $t_0 = -1.03$ yrs. The data for both species indicate that they are relatively fast growing, with most linear growth occurring in the first five years of life. Comparison between the growth data from Ling (1958) from other parts of the State and the present data show good agreement for two year old fish. However, after this age the mean lengths at age were higher for fish from Baird Bay than for other waters. The reasons for the differences are unknown, but may be due to biological differences, or errors in aging of otoliths. Ling (1958) used a slightly different method for aging otoliths (counting the annuli on cleaned whole otoliths with the aid of a hand lens), and refinement of the aging technique needs to be undertaken by comparing the two methods on the same pair of otoliths.

In spite of the problems in aging them, otoliths must be used because 1) scales are not easy to sample because of their ease in shedding when the fish is handled, 2) the lack of prominent modes in length frequency distributions in older year classes (Fig. 4), and 3) the unsuitability of tagging because of high mortality during handling and the lack of any substantial fishery by which large numbers of

tags can be returned. Therefore, because of the present inability to differentiate between biological and technical reasons for differences in growth estimation, if mortality rates are to be estimated for other areas and compared with the present results, age-length keys should be calculated using the same aging technique as that described above.

An assumption of the mortality estimates given here is that neither immigration nor emigration occurs. The present survey demonstrates that the Baird Bay population is probably a unit stock, because spawning occurs within the Bay, some juvenile fish were taken from beach seine shots, and the similarity in size of fish from the two largest mesh gill nets shows that the full size range was sampled. It is likely that there is no emigration of older fish to waters outside the bay, because of their absence in the landings from adjacent fisheries at Venus, Seales and Streaky Bays (unpubl. data).

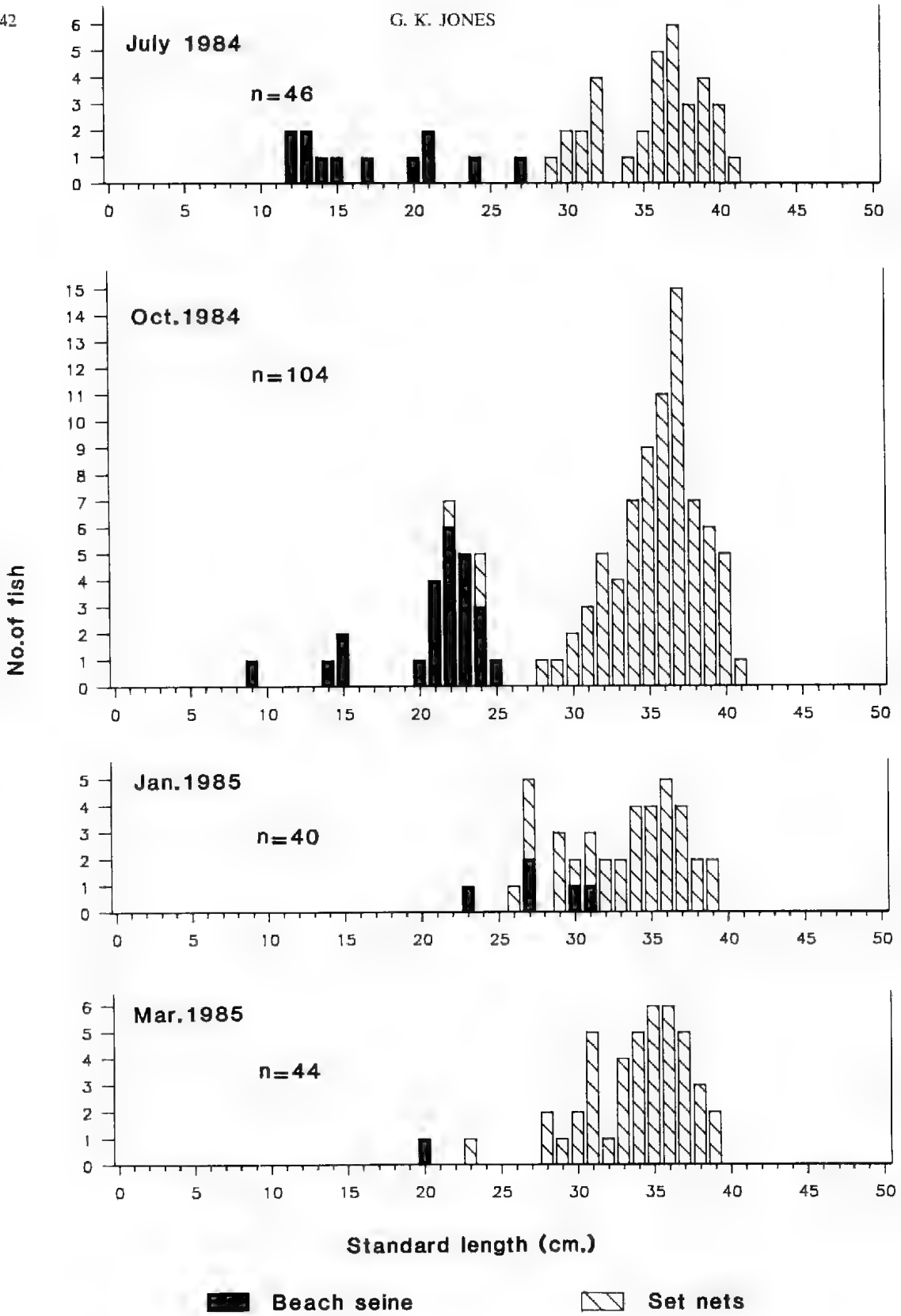
The two sets of estimates of natural mortality rate (M) are very similar for male fish; however, using Pauly's equation (1981) to calculate M for female fish the estimate of 0.57 is somewhat higher and inconsistent with the mean and standard error (0.35 ± 0.10) estimated from the age composition data. It is concluded that the method of Pauly may be useful as an initial crude estimate, because of the quantified assumption of the effect of schooling on the estimation of mortality.

Few estimates of natural mortality are available for comparison with those reported here. Berkely & Houde (1978) estimated an annual survival rate of 14% for the heavily fished species *H. brasiliensis* from 1–2 years of age, and Hughes (1974) estimated survival rates for the lightly fished Pacific saury (*C. sarda*) from 28.7% to 10.5%. Low annual survival rates are believed to be typical for fish of the Order Belontiiformes as they are important prey for a number of predators such as pelagic teleosts and seabirds (Ayling & Cox 1982). Although relatively large Australian salmon (*Arripis trutta espei*) were captured during the present investigation, analysis of stomach contents revealed that this species was not feeding on *H. melanochir* (unpubl. data).

The relatively high growth constant (k) and a high natural mortality rate (M) is important for determining fishing strategies. The importance of knowing the ratio M/k has been highlighted by

TABLE 1. Estimates of von Bertalanffy growth parameters (with standard errors) for *Hyporhamphus melanochir* from Baird Bay, South Australia.

GROWTH PARAMETER	MALES	FEMALES
Growth Constant (k)	0.507 (± 0.032)	0.540 (± 0.044)
Asymptotic Length (L_{∞})	36.7 (± 0.4) cm	38.7 (± 0.6) cm
Age at zero length (t_0)	-1.12 (± 0.08) yr	-1.10 (± 0.08) yr



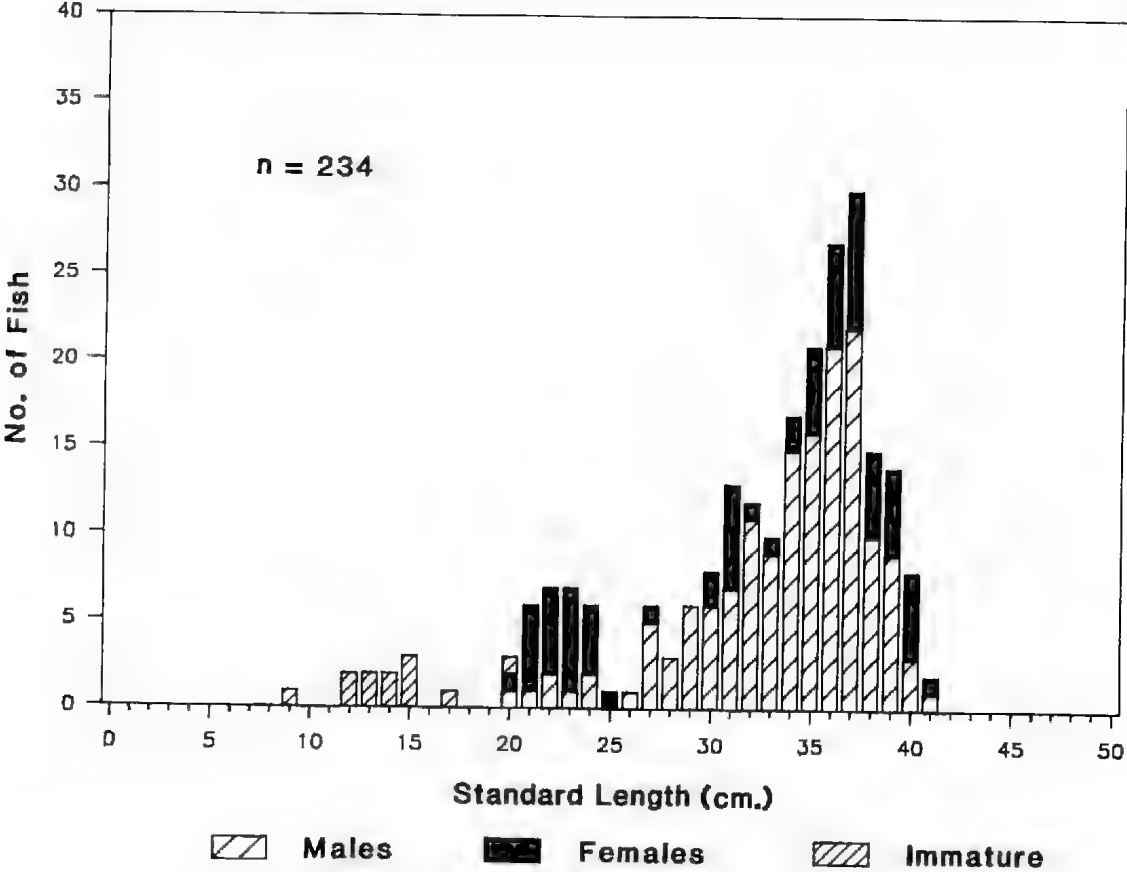


Fig. 5. Cumulative size composition of male, female and immature garfish in Baird Bay. (seasonal data and fishing methods combined).

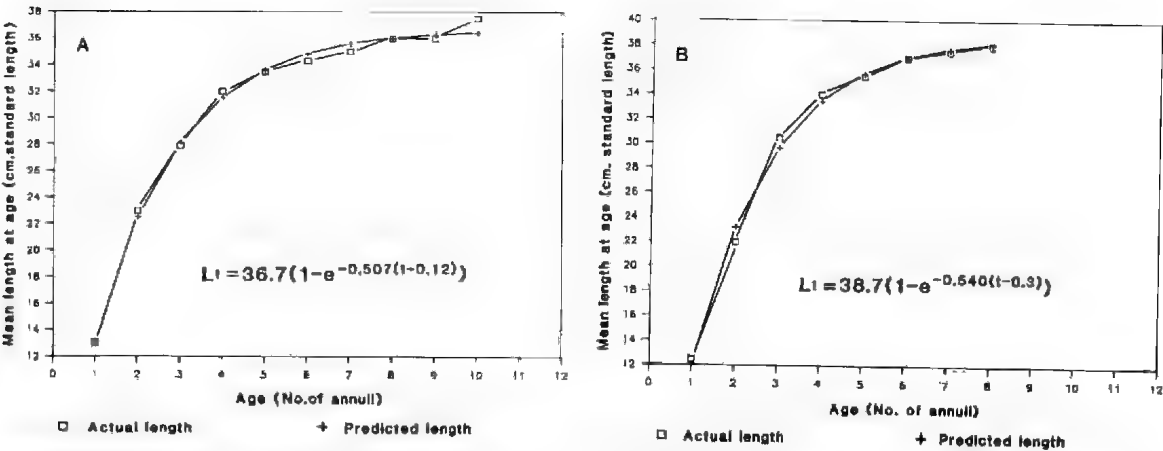


Fig. 6. Actual and predicted growth curves for male (A) and female (B) garfish in Baird Bay. (Predicted mean lengths-at-age obtained from von Bertalanffy growth parameters calculated from aging of otoliths.)

Fig. 4. Seasonal changes in size composition of garfish in Baird Bay, using beach seine and gill nets (mesh sizes and areas combined).

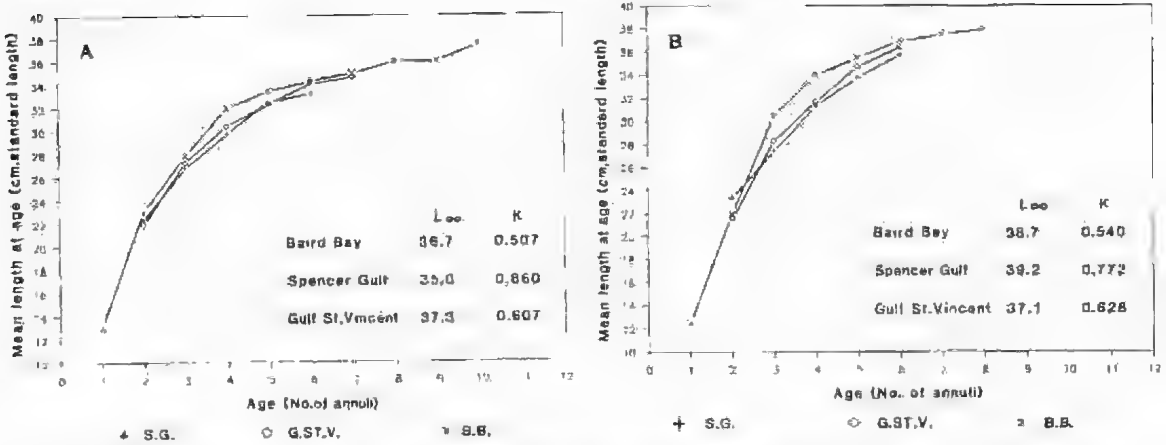


Fig. 7. Growth curves for male (A) and female (B) garfish from South Australian waters. (Growth parameters for Spencer Gulf and Gulf St Vincent determined from raw data in Ling (1958).)

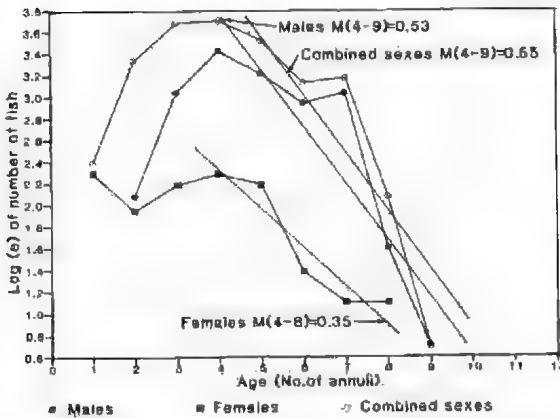


Fig. 8. Catch curves and estimated natural mortality rates for male, female and combined sexes of garfish in Baird Bay, determined from age composition data.

Beverton (1963). The ratio for male *H. melanochir* is 1.05, and for females 0.65 using the age composition data. These ratios are relatively low in comparison with some species, such as gadoids (Gulland 1983), and indicate that garfish populations will attain most of their potential growth before being greatly reduced through natural mortality. In the absence of fishing, (as is virtually the case in Baird Bay), this means that the stock contains many large fish, and in terms of

maximising the yield per recruit, it would be necessary to fish relatively lightly with a relatively high minimum length. In other areas of State waters, where fishing mortality is higher, the strategy may need to be different. To determine these strategies, however, yield per recruit relationships need to be generated for each area.

Another method for determining the best strategy in the fished populations is to experimentally manipulate the harvesting rates, as suggested by Walters & Hilborn (1976). Here, Baird Bay lends itself as a suitable research area where fishing effort could be manipulated and the resultant effects on the stock of garfish monitored.

Acknowledgments

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CATALOGUE OF INVERTEBRATE TYPE SPECIMENS HELD IN THE COLLECTIONS OF THE WAITE AGRICULTURAL RESEARCH INSTITUTE AND THE SOUTH AUSTRALIAN DEPARTMENT OF AGRICULTURE

*BY A. D. AUSTIN & V. BURNYOCZKY**

Summary

A catalogue of the type material of insects and other invertebrates held in the collections of the Waite Agricultural Research Institute (WARI) and the South Australian Department of Agriculture (SADA) is presented. Only paratypes are held in these collections; all primary types previously held have been transferred to the Australian National Insect Collection, Canberra. For each species the primary reference, location of the holotype, and the number of paratypes in WARI and SADA is provided. An account of the history, scope and importance of the collections is given.

KEY WORDS: catalogue, type specimens, Insecta, Arachnids

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Summary

AUSTIN, A. D. & BURNYOCZKY, V. (1990) Catalogue of invertebrate type specimens held in the collections of the Waite Agricultural Research Institute and the South Australian Department of Agriculture. *Trans. R. Soc. S. Aust.* 114(1), 47-53. 31 May, 1990.

A catalogue of the type material of insects and other invertebrates held in the collections of the Waite Agricultural Research Institute (WARI) and the South Australian Department of Agriculture (SADA) is presented. Only paratypes are held in these collections; all primary types previously held have been transferred to the Australian National Insect Collection, Canberra. For each species the primary reference, location of the holotype, and the number of paratypes in WARI and SADA is provided. An account of the history, scope and importance of the collections is given.

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Introduction

In South Australia identification of arthropods relevant to agriculture and forestry and related taxonomic research are serviced by specialized collections at the Waite Agricultural Research Institute, University of Adelaide, and the South Australian Department of Agriculture. These collections include over 250,000 specimens, many being authoritatively identified to species. Included are type specimens of more than 110 species in 25 families, a large proportion of which are of agricultural relevance. To date there has not been a catalogue published of the type holdings in these collections. As a result few systematists realise the scope and importance of these collections, whilst recent reorganisation and rationalisation of the Waite Institute's collection has involved the transfer of some type material to the Australian National Insect Collection, Canberra. Here we document the location, number and primary reference of the type material, and present a brief account of the history, scope and significance of the two collections.

History of the collections

The collection at the Waite Institute started soon after the appointment of the first entomologist, J. Davidson, in 1928. Under the terms of special State Government funding, Davidson was required to provide an advisory service in entomology to the Department of Agriculture and, later, to the Woods & Forest Service (Andrewartha 1945; Edgeloe 1984). Accordingly, Davidson requested that samples of agricultural pests be sent to him from South

Australia and adjacent States for the purpose of making identifications; this material formed the basis of the present collection.

Up to 1945 research on locusts and insects associated with crops, pastures and orchards (chiefly by Davidson, D. S. Swan and H. G. Andrewartha) added significantly to the collection. In 1950 H. S. F. Lower was appointed as the first systematic entomologist and curator of the collection. Although his interest in acalyptate Diptera and cicadellid bugs is not reflected in the collection's meagre holdings of these groups, his curatorship to the early 1960's saw further additions to the collection, mainly as a result of Swan's interest in Acarina and aculeate Hymenoptera, work on pest species of Lepidoptera by several workers and studies on the biology of pollination by K. M. Doull.

In 1959, P. R. Burks, appointed as the Department of Agriculture's first entomologist, started a separate collection, resulting in a decrease of reliance on the advisory service provided by the Waite Institute. Subsequently the two collections have developed in parallel: that at the Department of Agriculture primarily as a synoptic collection of invertebrates developed from material submitted for identification, and that at the Waite Institute from material originating from research work within the Department of Entomology.

From the early 1960's the Waite Institute collection developed significantly in two major areas: insects associated with native and planted forests because of the work of F. D. Morgan, and scale insects (Coccoidea) from taxonomic research by H. M. Brookes, who was curator from 1964 to 1982. In 1985 one of us (A.D.A.), with research interests in the systematics of hymenopteran parasitoids and biological control, was appointed lecturer in Systematic Entomology and became the

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third curator of the Waite Institute collection. In 1986, after the collection was transferred to a refurbished, air-conditioned room and was reorganized into new standard 10-drawer cabinets employing a unit-tray system, it was dedicated as the Duncan Swan Insect Collection, in honour of the contribution of Swan, who provided the major inspiration for expansion of the collection to its present size and importance.

In 1982 the Department of Agriculture using its Dec minicomputer, set up a data-base for storage and easy retrieval of taxonomic and biological information on arthropods relevant to agriculture and veterinary science (Caon *et al.* 1984). This system stores primary information from collections and/or card files at the Department of Agriculture, the Waite Institute, the Institute of Medical & Veterinary Science and the South Australian Museum. It enables rapid retrieval of information on taxonomic status, distribution, host association, abundance and damage assessment, and will undoubtedly be of great assistance in future extension work and entomological research in South Australia.

Notable holdings of importance to taxonomic research at the Department of Agriculture and Waite Institute include collections of acridid grasshoppers, scarabaeid beetles and larvae and other immature stages of groups injurious to plants. In addition the Waite Institute houses significant collections of Acarina, Araneae, Thysanoptera, Homoptera (chiefly Psylloidea and Coccoidea), Lepidoptera and parasitic Hymenoptera.

Catalogue of type material

The catalogue lists species published prior to 1989 for which type material is held in the two collections. For each species the primary reference, location of the holotype and number of paratypes is given. Holotypes reported in primary references to be located at the Waite Institute, have been transferred to the Australian National Insect Collection. Many paratypes have also been transferred, particularly for species of Coccoidea, as a large proportion of H. M. Brookes' collection was donated to ANIC in 1986 to aid with the centralization of coccoid research in Australia. Abbreviations of institutions are: AM, Australian Museum, Sydney; ANIC, Australian National Insect Collection, CSIRO, Canberra; BMNH, British Museum (Natural History), London; NZAC, New Zealand Arthropod Collection, DSIR, Auckland; QM, Queensland Museum, Brisbane; SADA, South Australian Department of Agriculture Collection, Adelaide; SAM, South

Australian Museum, Adelaide; USNM, United States National Museum (Natural History), Washington; WARI, Waite Agricultural Research Institute Collection, Adelaide.

ACARINA

Ixodidae

Amblyomma triguttatum ornaticornis Roberts, 1962, Aust. J. Zool. 10: 376.

Holotype, ♀, QM; Paratypes, 2♀, WARI.

INSECTA

BLATTODEA

Blaberidae

Ataxigamia tatei Tepper, 1893, Trans. R. Soc. S. Aust. 18: 123.

Holotype, ♂, SAM; Paratype, 1♂, WARI.

ORTHOPTERA

Gryllidae

Gryllulus subniger Chopard, 1951, Rec. S. Aust. Mus. 9: 417.

Holotype, ♂, SAM; Paratypes, 3♂♂, 2♀♀, WARI.

HETEROPTERA

Lygaeidae

Zygocoris tindalei Gross, 1962, Rec. S. Aust. Mus. 14: 381.

Holotype, ♂, SAM; Paratype, 1♀, WARI.

Pentatomidae

Minchamia hubbardae Gross, 1976, *Plant Feeding and Other Bugs (Hemiptera) of South Australia, Heteroptera — Part II*, Govt Printer, S. Aust., p.415.

Holotype, ♂, SAM; Paratype, 1♀, WARI.

HOMOPTERA

Cicadellidae

Empoasca delta Wheeler, 1939, J. Wash. Acad. Sci. 29: 299.

Holotype, ♂, USNM; Paratypes, 2♂♂, 1♀, WARI.

Empoasca dolonus Oman, 1936, J. Wash. Acad. Sci. 26: 39.

Holotype, ♂, USNM; Paratypes, 1♂, 1♀, WARI.

Empoasca ensiformis Oman & Wheeler, 1938, Proc. ent. Soc. Wash. 40: 142.

Holotype, ♂, USNM; Paratypes, 2♂♂, 2♀♀, WARI.

Aphalaridae

Platyobria maddeni Taylor, 1987, J. Aust. ent. Soc. 26: 256.

Holotype, ♂, ANIC; Paratypes, 1♂, 1♀, WARI.

Platyobria minima Taylor, 1987, J. Aust. ent. Soc. 26: 261.

Holotype, ♂, ANIC; Paratypes, 2♂♂, 2♀♀, WARI.

Spondylaspididae

Anoeconeossa communis Taylor, 1987, J. Aust. ent. Soc. 26: 113.

Holotype, ♂, ANIC; Paratypes 1♂, 1♀, WARI.

Anoeconeossa copidiformis Taylor, 1987, J. Aust. ent. Soc. 26: 118.

Holotype, ♂, ANIC; Paratypes 5♂♂, 10♀♀, WARI.

Anoeconeossa vespertina Taylor, 1987, J. Aust. ent. Soc. 26: 118.

Holotype, ♂, ANIC; Paratypes, 2♂♂, 2♀♀, WARI.

Blastopsylla adnatariae Taylor, 1985, J. Aust. ent. Soc. 24: 21.

Holotype, ♂, ANIC; Paratypes, 2♂♂, 3♀♀, WARI.

Blastopsylla occidentalis Taylor, 1985, J. Aust. ent. Soc. 24: 22.

Holotype, ♂, ANIC; Paratypes, 3♂♂, 2♀♀, WARI.

Blastopsylla octosetulae Taylor, 1985, J. Aust. ent. Soc. 24: 24.

Holotype, ♂, ANIC; Paratypes, 2♂♂, 2♀♀, WARI.

Cardiaspina albitextura Taylor, 1962, Aust. J. Zool. 10: 332.

Holotype, ♀, ANIC; Paratypes, 1♂, 1♀, WARI.

Cardiaspina densitexta Taylor, 1962, Aust. J. Zool. 10: 334.

Holotype, ♀, ANIC; Paratypes, 30♀♀, WARI.

Cardiaspina relator Taylor, 1962, Aust. J. Zool. 10: 317.

Holotype, ♀, ANIC; Paratypes, 1♂, 1♀, WARI.

Glycaspis (Glycaspis) fuscavena Moore, 1970, Aust. Zool. 15: 288.

Holotype, ♂, ANIC; Paratypes, 6♂♂, WARI.

Glycaspis (Alloglycaspis) repentina Moore, 1964, Proc. Linn. Soc. N.S.W. 89: 148.

Holotype, ♂, AM; Paratypes, 7♂♂, 1♀, WARI.

Glycaspis (Alloglycaspis) wanhiensis Moore, 1964, Proc. Linn. Soc. N.S.W. 89: 148.

Holotype, ♂, AM; Paratypes, 4♂♂, 3♀♀, WARI.

Triozidae

Schedotrioxa marginata Taylor, 1987, J. Aust. ent. Soc. 26: 233.

Holotype, ♂, ANIC; Paratypes, 31♂♂, 18♀♀, WARI.

Asterolecaniidae

Frenchia banksiae Lambden & Kosztarab, 1981, Proc. ent. Soc. Wash. 83: 109.

Holotype, ♀, ANIC; Paratypes, 8 Juv., WARI.

Coccidae

Symonicoccus aberrans Koteja & Brookes, 1981, Polskie Pismo ent. 51: 384.

Holotype, ♀, ANIC; Paratype, 1♀, WARI.

Symonicoccus chorizandrae Koteja & Brookes, 1981, Polskie Pismo ent. 51: 387.

Holotype, ♀, ANIC; Paratypes, 2♀♀, WARI.

Symonicoccus stipae Koteja & Brookes, 1981, Polskie Pismo ent. 51: 383.

Holotype, ♀, ANIC; Paratype, 1♀, WARI.

Diaspididae

Odonaspis australiensis Ben-Dov, 1988, U.S. Nat. Mus. Tech. Bull. 1723: 37.

Holotype, ♀, ANIC; Paratypes, 3♀♀, WARI.

Lecanodiaspididae

Brookesiella tuberans Lambden & Kosztarab, 1974, Ann. ent. Soc. Am. 67: 409.

Holotype, ♀, ANIC; Paratypes, 2♀♀, WARI.

Lecanodiaspis eremocii Howell & Kosztarab, 1974, Virg. Polytech. Inst. & State Univ. Div. Bull. 70: 41.

Holotype, ♀, ANIC; Paratypes, 2♀♀, WARI.

Pseudococcidae

Aciniccoccus stipae Williams, 1985, Australian Mealybugs, BMNH, p.42.

Holotype, ♀, ANIC; Paratypes, 2♀♀, WARI.

Aciniccoccus triodiae Williams, 1985, Australian Mealybugs, BMNH, p.42.

Holotype, ♀, ANIC; Paratypes, 3♀♀, WARI.

Apodastococcus onar Williams, 1985, Australian Mealybugs, BMNH, p.48.

Holotype, ♀, ANIC; Paratypes, 3♀♀, WARI.

Australiputō eucalypti Williams, 1985, Australian mealybugs, BMNH, p.63.

Holotype, ♀, ANIC; Paratypes, 3♀♀, WARI.

Chaetotrionymus murnpeowiensis Williams, 1985, Australian Mealybugs, BMNH, p.72.

Holotype, ♀, ANIC; Paratypes, 2♀♀, WARI.

Chaetotrionymus pachylux Williams, 1985, Australian Mealybugs, BMNH, p.72.

Holotype, ♀, ANIC; Paratypes, 4♀♀, WARI.

Chorizococcus eriachnis Williams, 1985, Australian Mealybugs, BMNH, p.79.

Holotype, ♀, ANIC; Paratypes, 3♀♀, WARI.

Chorizococcus lii Brookes, 1977, J. Aust. ent. Soc. 15: 422.

= *Cryptoripersia lii* (Brookes) vide Williams, 1985, Australian Mealybugs, BMNH, p.102.

Holotype, ♀, ANIC; Paratypes, 2♀♀, WARI.

Chorizococcus petilus Brookes, 1977, J. Aust. ent. Soc. 15: 425.

= *Humococcus petilus* (Brookes) vide Williams, 1985, Australian Mealybugs, BMNH, p.178.

Holotype, ♀, ANIC; Paratype, 1♀, WARI.

- Chorizococcus radicalis* Brookes, 1977, J. Aust. ent. Soc. 15: 427.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
= *Vryburgia brevicurvis* (McKenzie) syn. Williams, 1985, Australian mealybugs, BMNH, p.387.
- Chorizococcus suhalpinus* Brookes, 1976, J. Aust. ent. Soc. 15: 429.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Coorongia gahniae* Williams, 1985, Australian Mealybugs, BMNH, p.92.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Crisicoccus acaciae* Williams, 1985, Australian Mealybugs, BMNH, p.95.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Cypselococcus multipori* Williams, 1985, Australian Mealybugs, BMNH, p.103.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Dysmicoccus aggeris* Williams, 1985, Australian Mealybugs, BMNH, p.111.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Dysmicoccus unicus* Williams, 1985, Australian Mealybugs, BMNH, p.111.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Dysmicoccus laportae* Williams, 1985, Australian Mealybugs, BMNH, p.133.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Dysmicoccus mounds* Williams, 1985, Australian Mealybugs, BMNH, p.137.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Dysmicoccus victorianus* Williams, 1985, Australian Mealybugs, BMNH, p.149.
Holotype, ♀, ANIC; Paratypes, 2 ♀ ♀, WARI.
- Eucalyptococcus brookesae* Williams, 1985, Australian Mealybugs, BMNH, p.155.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Eurycoccus antiscius* Williams, 1985, Australian Mealybugs, BMNH, p.161.
Holotype, ♀, BMNH; Paratypes, 2 ♀ ♀, WARI.
- Eurycoccus yanchepae* Brookes, 1972, J. Aust. ent. Soc. 11: 132.
Holotype, ♀, ANIC; Paratypes, 2 ♀ ♀, WARI.
= *Macronellicoccus lanigerus* (Fuller) syn. Williams, 1985, Australian Mealybugs, BMNH, p.196.
- Hadrococcus maireanae* Williams, 1985, Australian Mealybugs, BMNH, p.169.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Hadrococcus pulpenueae* Williams, 1985, Australian Mealybugs, BMNH, p.169.
Holotype, ♀, ANIC; Paratypes, 2 ♀ ♀, WARI.
- Helicococcus summervillei* Brookes, 1978, J. Aust. ent. Soc. 17: 241.
Holotype, ♀, ANIC; Paratypes, 2 ♀ ♀, WARI.
- Ityococcus beardsleyi* Williams, 1985, Australian Mealybugs, BMNH, p.180.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Ityococcus eremocitri* Williams, 1985, Australian Mealybugs, BMNH, p.183.
Holotype, ♀, ANIC; Paratypes, 2 ♀ ♀, WARI.
- Ityococcus milparinkae* Williams, 1985, Australian Mealybugs, BMNH, p.185.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Luminicoccus flandensis* Williams, 1985, Australian Mealybugs, BMNH, p.190.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Melanococcus coharicus* Williams, 1985, Australian Mealybugs, BMNH, p.209.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Melanococcus darwiniensis* Williams, 1985, Australian Mealybugs, BMNH, p.209.
Holotype, ♀, ANIC; Paratypes, 5 ♀ ♀, WARI.
- Melanococcus morgani* Williams, 1985, Australian Mealybugs, BMNH, p.217.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Melanococcus phylodii* Williams, 1985, Australian Mealybugs, BMNH, p.219.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Melanococcus senticosus* Williams, 1985, Australian Mealybugs, BMNH, p.221.
Holotype, ♀, ANIC; Paratypes, 2 ♀ ♀, WARI.
- Melanococcus tasmaniae* Williams, 1985, Australian Mealybugs, BMNH, p.223.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Nipaeococcus exocarpi* Williams, 1985, Australian Mealybugs, BMNH, p.237.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Nipaeococcus maireanae* Williams, 1985, Australian Mealybugs, BMNH, p.240.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Peliococcus subcorticicola* Williams, 1985, Australian Mealybugs, BMNH, p.257.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Phenacoccus hakeae* Williams, 1985, Australian Mealybugs, BMNH, p.270.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Poecilococcus longilobus* Brookes, 1981, J. Aust. ent. Soc. 20: 127.
Holotype, ♀, ANIC; Paratypes, 6 ♀ ♀, WARI.

- Pseudococcus atalestus* Williams, 1985, Australian Mealybugs, BMNH, p.287.
Holotype, ♀, ANIC; Paratypes, 2 ♀ ♀, WARI.
- Pseudococcus chenopodii* Williams, 1985, Australian Mealybugs, BMNH, p.294.
Holotype, ♀, ANIC; Paratypes, 3 ♀ ♀, WARI.
- Pseudococcus eremophilae* Williams, 1985, Australian Mealybugs, BMNH, p.306.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Pseudococcus eucalypticus* Williams, 1985, Australian Mealybugs, BMNH, p.310.
Holotype, ♀, ANIC; Paratypes, 3 ♀ ♀, WARI.
- Pseudococcus goodeniae* Williams, 1985, Australian Mealybugs, BMNH, p.313.
Holotype, ♀, ANIC; Paratypes, 2 ♀ ♀, WARI.
- Pseudococcus hypergaeus* Williams, 1985, Australian Mealybugs, BMNH, p.315.
Holotype, ♀, ANIC; Paratypes, 2 ♀ ♀, WARI.
- Pseudococcus mintarivus* Williams, 1985, Australian Mealybugs, BMNH, p.320.
Holotype, ♀, ANIC; Paratypes, 2 ♀ ♀, WARI.
- Pseudococcus onustus* Williams, 1985, Australian Mealybugs, BMNH, p.320.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Pseudococcus symoni* Williams, 1985, Australian Mealybugs, BMNH, p.333.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Rhastrococcus melaleuciae* Williams, 1985, Australian Mealybugs, BMNH, p.345.
Holotype, ♀, ANIC; Paratypes, 3 ♀ ♀, WARI.
- Rhizococcus sphagni* Williams, 1985, Australian Mealybugs, BMNH, p.357.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Trionymus ascripticius* Williams, 1985, Australian Mealybugs, BMNH, p.368.
Holotype, ♀, ANIC; Paratypes, 4 ♀ ♀, WARI.
- Trionymus gyrus* Williams, 1985, Australian Mealybugs, BMNH, p.371.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Trionymus zoysiae* Williams, 1985, Australian Mealybugs, BMNH, p.377.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Ventrispina epigaea* Williams, 1985, Australian Mealybugs, BMNH, p.378.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Ventrispina lathetica* Williams, 1985, Australian Mealybugs, BMNH, p.378.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Ventrispina woodi* Williams, 1985, Australian Mealybugs, BMNH, p.381.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Vryburgia succulentarum* Williams, 1985, Australian Mealybugs, BMNH, p.388.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.
- Yudnapinna radialis* Williams, 1985, Australian Mealybugs, BMNH, p.390.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.

THYSANOPTERA

Aeolothripidae

Craniothrips sititor Mound, 1972, J. Aust. ent. Soc. 11: 44.
Holotype, ♀, ANIC; Paratypes, 1 ♂, 2 ♀ ♀, WARI.

Craniothrips vesper Mound, 1972, J. Aust. ent. Soc. 11: 46.
Holotype, ♀, ANIC; Paratypes, 6 ♂ ♂, 6 ♀ ♀, WARI.

Desmothrips davidsoni Morison, 1931, Bull. ent. Res. 21: 499.

Holotype, ♀, BMNH; Paratype, 1 ♀, WARI.
= *Desmothrips tenuicornis* (Bagnall) syn. Mound, 1967, Bull. Br. Mus. nat. Hist. Ent. 20: 68.

Desmothrips elegans Morison, 1931, Bull. ent. Res. 21: 451.
Holotype, ♀, BMNH; Paratypes, 2 ♀ ♀, WARI.
= *Desmothrips propinquus* (Bagnall) syn. Mound, 1967, Bull. Br. Mus. nat. Hist. Ent. 20: 65.

Phlaeothripidae

Csirothrips watsoni Mound, 1971, Bull. Br. Mus. nat. Hist. Ent. 25: 399.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.

Onchothrips arotum Mound, 1971, Bull. Br. Mus. nat. Hist. Ent. 25: 447.
Holotype, ♀, ANIC; Paratypes, 2 ♀ ♀, WARI.

Warithrips maelzeri Mound, 1971, Bull. Br. Mus. nat. Hist. Ent. 25: 456.
Holotype, ♀, ANIC; Paratype, 1 ♀, WARI.

Thripidae

Odontothripella andrewarthae Pitkin, 1972, J. Aust. ent. Soc. 11: 271.
Holotype, ♂, ANIC; Paratype, 1 ♂, WARI.

Odontothripella compta Pitkin, 1972, J. Aust. ent. Soc. 11: 275.
Holotype, ♂, ANIC; Paratypes, 1 ♂, 1 ♀, WARI.

Odontothripella concolorata Pitkin, 1972, J. Aust. ent. Soc. 11: 278.
Holotype, ♀, ANIC; Paratypes, 4 ♀ ♀, WARI.

Odontothripella hopei Pitkin, 1972, J. Aust. ent. Soc. 11: 281.

Holotype, ♂, ANIC; Paratypes, 1♂, 2♀ ♀, WARI.

Odontothripella passalaina Pitkin, 1972, J. Aust. ent. Soc. 11: 28.

Holotype, ♂, ANIC; Paratypes, 1♂, 2♀ ♀, WARI.

Physothrips simplex Morison, 1930, Bull. ent. Res. 21: 12. = *Thrips simplex* (Morison) vide Bhatti, 1969, Orient. Insects 3: 380.

Holotype ♀, BMNH; Paratype, 1♀, WARI.

NEUROPTERA

Chrysopidae

Chrysopa australis New, 1980, Aust. J. Zool. Suppl. Ser. 77: 42.

Holotype, ♀, ANIC; Paratypes, 1♂, 2♀ ♀, WARI.

COLEOPTERA

Cerambycidae

Uracanthus cupressianus Rondonuwu & Austin, 1988, Trans. R. Soc. S. Aust. 112: 110.

Holotype, ♂, SAM; Paratypes, 21♂♂, 20♀ ♀, WARI.

Scaphaeidae

Colpochila kalambii Britton, 1986, Aust. J. Zool. Suppl. Ser. 118: 54.

Holotype, ♂, ANIC; Paratypes, 1♂, 1♀, SADA.

Telura petiolata Britton, 1987, Invertebr. Taxon. 1: 702.

Holotype, ♂; ANIC; Paratype, 1♂, SADA.

DIPTERA

Apioceridae

Apiocera helenae Paramonov, 1953, Aust. J. Zool. 1: 483.

Holotype, ♂, ANIC; Paratypes, 2♀ ♀, 3♂♂, WARI.

Stratiomyidae

Damaromyia interrupta James, 1950, Proc. ent. Soc. Wash. 52: 313.

Holotype, ♀, BMNH; Paratype, 1♂, WARI.

HYMENOPTERA

Braconidae

Apanteles ulfulfae Nixon, 1960, Ann. Mag. nat. Hist. (13) 2: 303.

= *Iconella ulfulfae* (Nixon) vide Mason, 1980, Mem. ent. Soc. Can. 115: 75.

Holotype, ♀, BMNH; Paratypes, 5♂♂, 2♀-♀, WARI.

Apanteles penthocratus Austin, 1987, In M. J. W. Cock *et al.* (Eds) Slug and Nettle Caterpillars, CAB International, p.148.

Holotype, ♀, BMNH; Paratypes, 1♂, 2♀ ♀, WARI.

Fornicia muluensis Austin, 1987, In M. J. W. Cock *et al.* (Eds) Slug and Nettle Caterpillars, CAB International, p.157.

Holotype, ♀, BMNH; Paratypes, 4♂♂, 1♀, WARI.

Ichneumonidae

Temelucha cycnea Kerrich, 1959, Ann. Mag. nat. Hist. (13) 2: 53.

Holotype, ♀, BMNH; Paratypes, 3♂♂, 2♀ ♀, WARI.

Scelionidae

Ceratobaeus clubionus Austin, 1983, Int. J. Insect Morph. Embryol. 12: 151; types designated Austin, 1984, Trans. R. Soc. S. Aust. 108: 23.

Holotype, ♀, ANIC; Paratypes, 1♂, 4♀ ♀, WARI.

Ceratobaeus cuspidicornatus Austin, 1983, Int. J. Insect Morph. Embryol. 12: 151; types designated Austin, 1984, Trans. R. Soc. S. Aust. 108: 25.

Holotype, ♀, ANIC; Paratypes, 1♂, 2♀ ♀, WARI.

Ceratobaeus masneri Austin, 1983, Int. J. Insect Morph. Embryol. 12: 143; types designated Austin, 1984, Trans. R. Soc. S. Aust. 108: 29.

Holotype, ♀, ANIC; Paratypes, 1♂, 4♀ ♀, WARI.

Ceratobaeus platycornutus Austin, 1984, Trans. R. Soc. S. Aust. 108: 30.

Holotype, ♀, ANIC; Paratypes, 1♂, 4♀ ♀, WARI.

Hickmanella holoplalya Austin, 1981, J. Aust. ent. Soc. 20: 306.

Holotype, ♀, ANIC; Paratypes, 2♀ ♀, WARI.

Mirobaeoides elongatus Austin, 1986, Aust. J. Zool. 34: 323.

Holotype, ♀, ANIC; Paratype, 1♀, WARI.

Mirobaeoides kerryi Austin, 1986, Aust. J. Zool. 34: 325.

Holotype, ♀, ANIC; Paratype, 1♀, WARI.

Mirobaeoides scutellaris Austin, 1986, Aust. J. Zool. 34: 328.

Holotype, ♀, ANIC; Paratype, 1♀, WARI.

Mirobaeoides setosus Austin, 1986, Aust. J. Zool. 34: 322.

Holotype, ♀, ANIC; Paratype, 1♀, WARI.

Neobaesus novaezealandensis Austin, 1988, N.Z. J. Zool. 15: 176.

Holotype, ♀, NZAC; Paratypes, 1♂, 9♀ ♀, WARI.

Psyllobaesus peckii Austin, 1984, Syst. Ent. 9: 123.

Holotype, ♀, ANIC; Paratypes, 1♂, 1♀, WARI.

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TRANSACTIONS OF THE

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NOTES ON THE HERBRIDAE (INSECTA: HEMIPTERA-HETEROPTERA) OF AUSTRALIA WITH DESCRIPTIONS OF THREE NEW SPECIES

BY IVOR LANSBURY*

Summary

The two known species of Australian Hebridae are redescribed. Keys to genera and species are provided.

Three new species, *Hebrus woodwardi* sp. Nov., *H. monteithi* sp. Nov. and *H. nourlangiei* sp. Nov. are described from Queensland and the Northern Territory. Lectotypes are designated from *Hebrus axillaries* Horváth and *Naeogeus latensis* Hale. Distributional and field notes are given for all the species.

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The two known species of Australian Hebridae are redescribed. Keys to genera and species are provided. Three new species, *Hebrus woodwardi* sp. nov., *H. monteithi* sp. nov. and *H. nauriangiei* sp. nov. are described from Queensland and the Northern Territory. Lectotypes are designated for *Hebrus axillaris* Horváth and *Naeoagaeus lutensis* Hale. Distributional and field notes are given for all the species.

KEY WORDS: Hebridae, *Hebrus*, *Merragata*, distribution.

Introduction

The described Australian hebrid fauna is small with two species, *Hebrus axillaris* Horváth (= *Naeoagaeus latensis* Hale) and *Merragata hackeri* Hungerford. *Hebrus* is a cosmopolitan genus which has been split into a number of subgenera of disputed validity. The most recent comprehensive account of the Hebridae is that of Andersen (1982) who estimates that there are about 110 species. Lundblad (1933) gives an overview of the family listing twelve species from the Indo-Australian Pacific region, two species being listed from New Guinea. At present there are 18 *Hebrus* species recorded from the Oriental region, additional species being described from the Philippines (Porter 1954, 1959) and Formosa (Taiwan) (Miyamoto 1964, 1965). The related Oriental genera, *Timasius* Distant, *Neotimasius* Andersen and *Hylcanus* Distant have been revised by Andersen (1981). These genera are known from the Indian sub-continent, Sri Lanka, Thailand, Malaya, Sumatra, Java and a single record from China. All the species appear to be hygropetric occurring on wet rock faces or in the splash zone of flowing water. The absence of records from New Guinea and 'northern' Australia may reflect lack of collecting rather than the absence of suitable habitats.

The genus *Hebrus* was split into six subgenera by Andersen (1981). Cobben (1982) suggested that the use of subgeneric groupings should be abandoned and no attempt has been made here to assign Australian *Hebrus* to subgenera. The Australian *Hebrus* species so far known form a diverse group which is difficult to characterise in species group descriptions.

The Hebridae are characterised within the Gerromorpha by the presence of a pair of prominent plates or bucculae on the ventral surface of the head which cover the base of the rostrum.

The tarsi of all legs are two-segmented, the first is always very short.

Andersen (1982) comments that the male genitalia of hebrids are always hidden from view when viewed dorsally. One new species described from Queensland differs in that the parameres (claspers of Andersen 1982) are clearly visible from the dorsal aspect.

Hebrids are small (1.5-2.0 mm long) stout bodied bugs. *Hebrus* is covered dorsally with a velvety hydrofuge-like pile. Depending upon the angle of viewing, the dorsal surface is variously iridescent. The underside is not so densely velvety pilose; sternites are usually shining with adpressed white or golden hairs. The hind legs are always slightly longer than the front and middle pairs and legs are usually equally spaced. All tarsal claws are apical. The ocelli and scutellum (metanotal elevation of Andersen 1982) are well developed in winged forms. *Merragata* is much like *Hebrus* but the dorsal pilosity, especially of the head being longer and not iridescent.

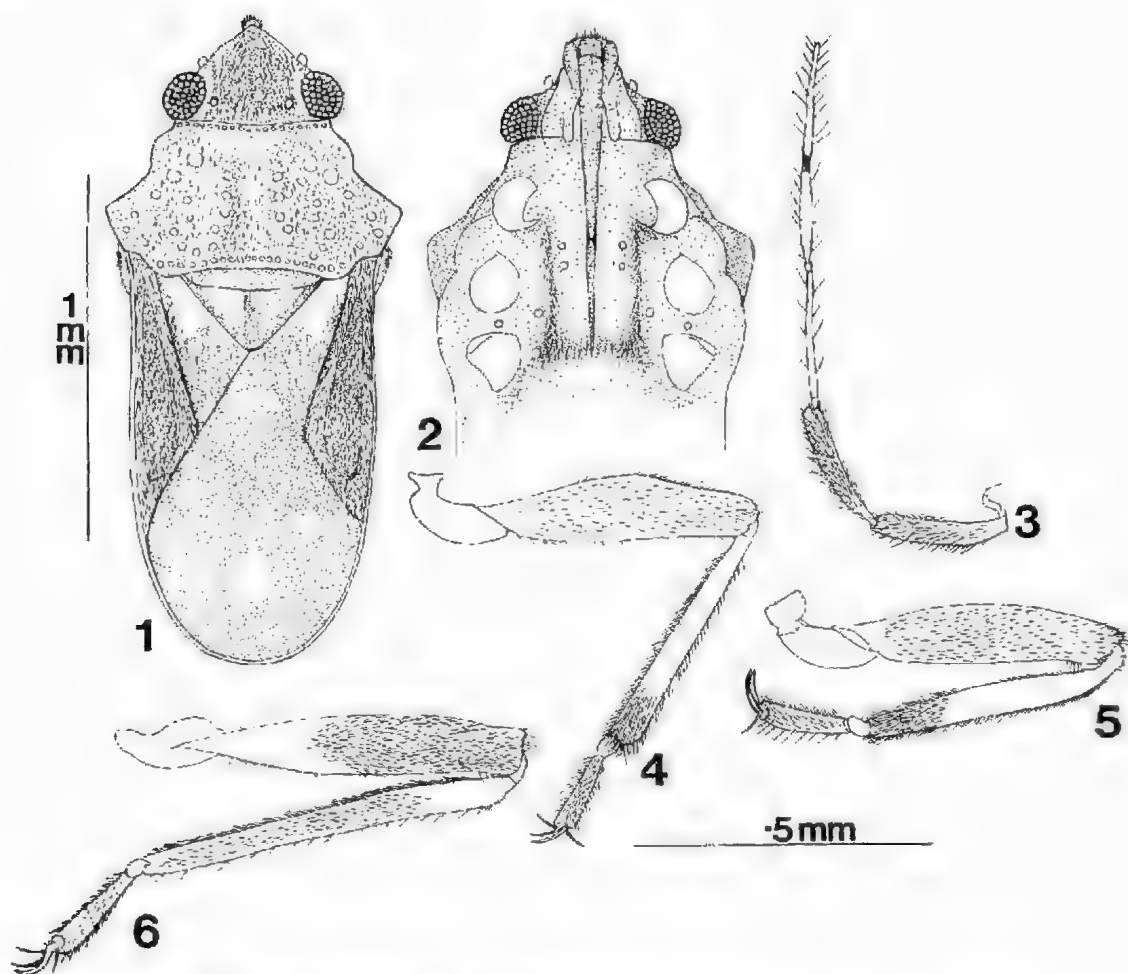
Key to Australian genera of Hebridae

- Antennae subflagelliform. Fourth segment subdivided by a coil-like or membranous zone. Antennal length subequal or longer than the greatest width of the pronotum. *Hebrus* Curtis, 1833
- Antennal segments short and club-like. Fourth segment not subdivided. Antennal length distinctly shorter than the greatest width of the pronotum.
- *Merragata* Buchanan-White, 1877

Key to the Australian species of *Hebrus*

- 1 Apex of scutellum acuminate, not bifurcate (Fig. 1) 2
- Apex of scutellum not acuminate but slightly bifurcate (Fig. 18). *H. nauriangiei* sp. nov.
- 2 Elytral membrane clearly not reaching the end of the abdomen especially in the male (Fig. 13). Parameres projecting beyond the end of the abdomen (Fig. 14) *H. monteithi* sp. nov.
- Elytral membrane almost reaching or surpassing the end of the abdomen (Fig. 7). Parameres not projecting beyond genital capsule. 3

* Hope Entomological Collections, University Museum, Oxford, U.K. OX1 3PW



Figs 1-6. *Hebrus axillaris* Horváth; 1, dorsum Lectotype ♀; 2, ventral aspect of head and thorax; 3, antennae; 4, fore leg; 5, middle leg; 6, hind leg. Sundown N.P., Qld ♂.

3 Elytral membrane almost reaching the end of the abdomen (Fig. 1). Third antennal segment 1.5× length of the 2nd segment. *H. axillaris* Horváth
Elytral membrane just surpassing the end of the abdomen (Fig. 7). Third antennal segment 2× length of the 2nd segment. *H. woodwardi* sp. nov.

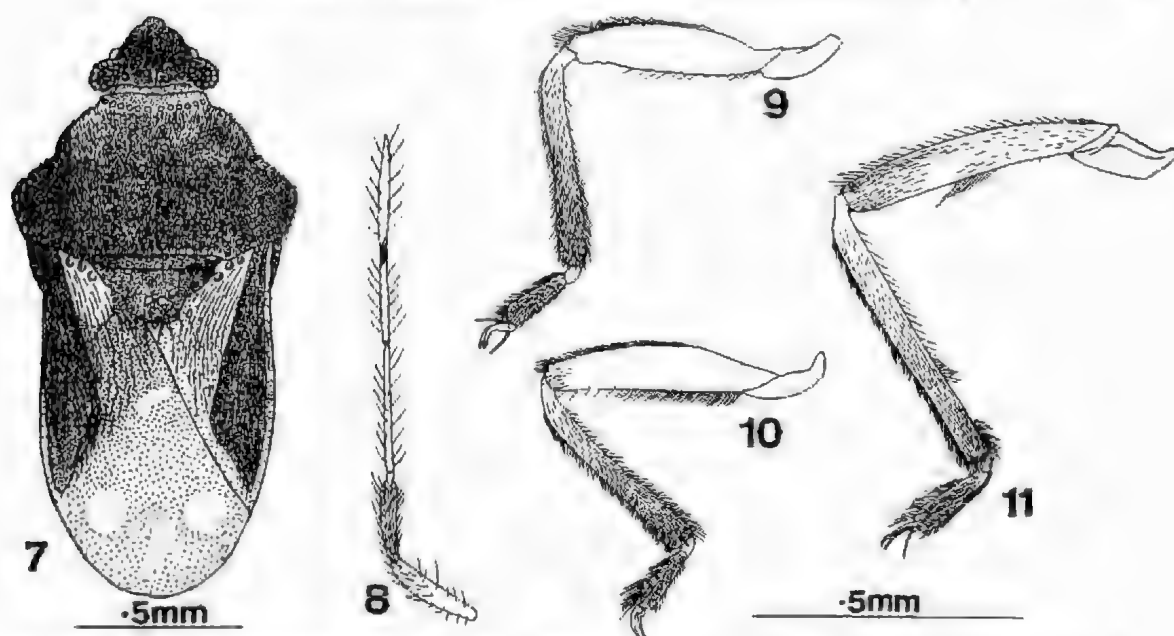
Hebrus axillaris Horváth
FIGS 1-6, 25, 30

Hebrus axillaris Horváth, 1902, p. 606; Lundblad, 1933, p. 263 (synonymy of *Nueogeus latensis* Hale, 1926 with *axillaris*); Hungerford, 1934, p. 70, (distribution Qld.).
Nueogeus latensis Hale, 1926, pp. 196-198.

Types: Lectotype female and 2 ♀♀ paralectotypes, New South Wales, Tweed River, A. M. Lea in the Hungarian Natural History Museum, Budapest, vid.

Distribution: S. Aust., N.S.W., Vic., Tas. and Qld.
Size: ♂♂, ♀♀ 1.7 - 2 mm long, width across widest part of pronotum .75 - .85 mm

Colour: Variable, head and anterior 1/3 of pronotum pale orange brown to black. Margins round eyes silvery tomentose. Antennae dark brown. Pronotum reddish brown with two (1+1) black areas medianly. Mesoscutellar lobe and scutellum dark brown. Head, pronotum and scutellum with short fine iridescent spicules. Forewings dark brown with long golden hairs and with greyish white patches proximally adjacent to scutellum and hind margin of pronotum. Membrane dark smokey brown with paler areas. Underside of head and bucculae pale yellow. Pleurites mostly black with posterior margin of propleura reddish brown. Legs yellowish brown. Sternites shining black with short silvery pubescence. 'Dark form' head black, medianly reddish brown. Pronotum anteriorly narrowly black, remainder reddish brown. Scutellum and forewings including membrane black. Forewings with two (1+1) white patches and long golden



Figs 7-11 *Hebrus woodwardi* sp. nov. Paratype ♂, Split Rock, Qld. 7, dorsum; 8, antennae; 9, fore leg; 10, middle leg; 11, hind leg

pubescence. Underside black with sparse silvery pubescence.

Fresh or very recently collected material tends to be darker than old specimens.

Structure: Interocular space about $2\times$ maximum eye width. Median head length about .66 median head width. Tubercles adjacent to antennal insertions small (Fig. 1). Antennae 1:2:3:4: - 7.5-7.5-13.5. First and 3rd antennal segments subequal, 2nd clearly shorter, 4th more or less subequal to combined lengths of 2nd and 3rd segments and subdivided by coil-like section (Fig. 3). Vertex with pair of median longitudinal furrows converging posteriorly. Bucculae short just reaching pronotum with two shallow depressions (Fig. 25). Lower margin straight with caudal or free end slightly curved.

Pronotal width $2\times$ its median length and head head width across eyes. Posterior margin with two (1+1) lobes either side of scutellum. Pronotum at its broadest slightly elevated and rugose. Median lateral angles depressed. Mesoscutellar lobe and scutellum half median length of pronotum. Scutellum ridged longitudinally and laterally forming two shallow depressions either side of mid line. Connexivum visible around membrane. Rostrum reaching hind coxae.

Front femur slightly more robust than middle femur (Figs 4 & 5). Hind femur slightly longer than median pronotal length. No significant differences in ratios of front and middle legs between males

and females. Hind legs $1.3\times$ longer than front and middle legs.

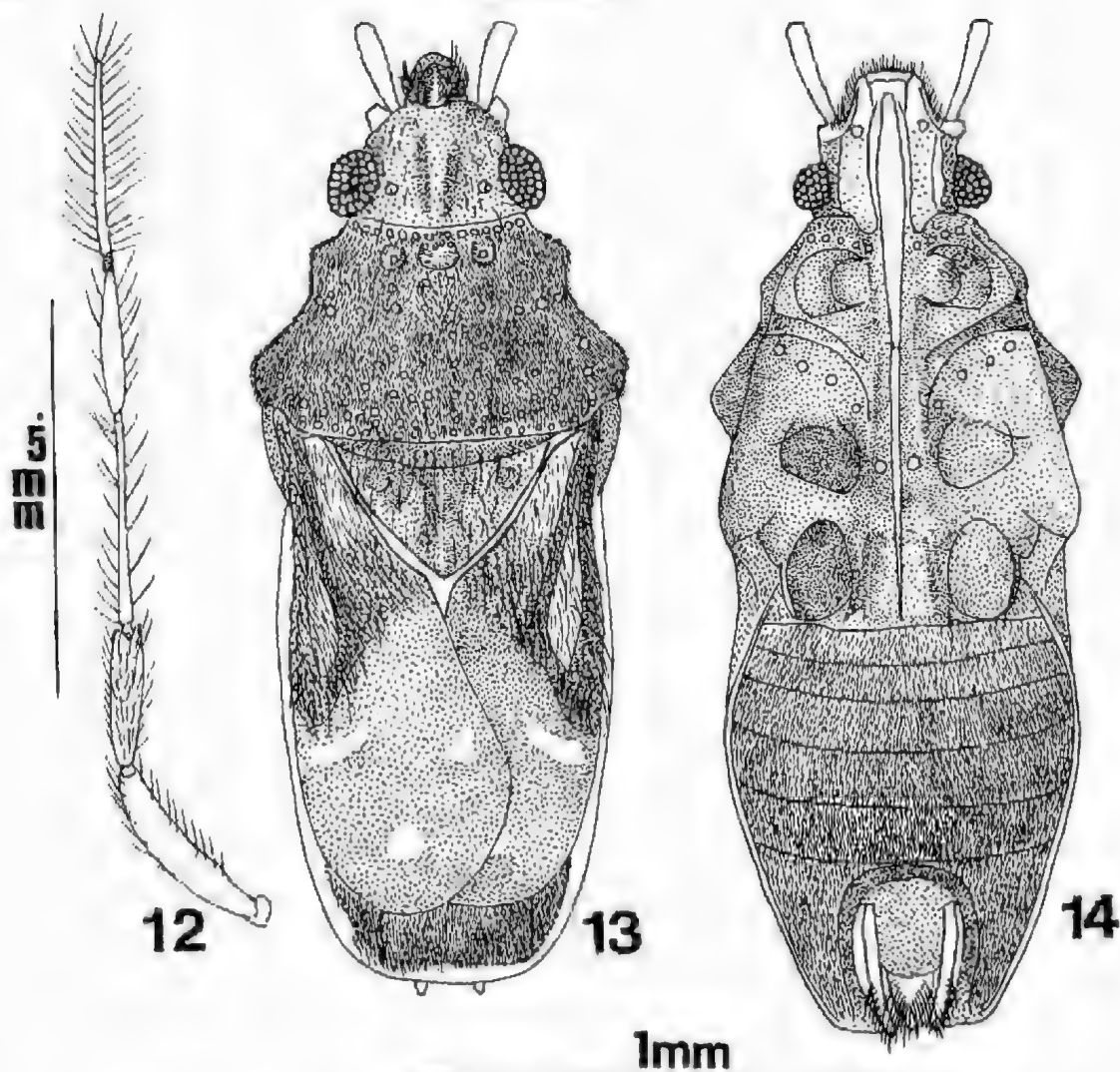
Male genital capsule (Fig. 30).

Lectotype Designation: Horváth's original description does not state on how many specimens from the type locality he based the description. In the Hungarian National Museum there are three specimens, originally mounted on a piece of card; labelled - N.S.W. Tweed R.; Lea; 3-92. A printed red label 'TYPUS'. A label in Horváth's handwriting - *Hebrus axillaris* Horv. and a hand written label '75 IIV WF'. The types are all females, they have been remounted individually on card points on one pin. One 'point' has been marked with a red spot, this female is designated and labelled Lectotype, the remaining two females are designated paralectotypes.

Notes on the type series of *Nacogeus latensis* Hale.

The 'type series' is in the South Australian Museum, Adelaide. Hale (1926: 197) gives 'Adelaide' as the type locality. Mounted on a piece of card labelled 'TYPE', Torrens River, Adelaide, Herbert M. Hale are a ♂ & ♀. The ♂ is almost certainly the specimen figured by Hale (1926: 197; Fig. 81). This ♂ is designated and labelled Lectotype, the accompanying ♀ is labelled and designated paralectotype.

There is some ambiguity about the remainder of Hale's type series as he did not give a precise locality other than Adelaide. There are four series of carded



Figs 12-14. *Hebrus mantelli* sp. nov. Paratype ♂, Wallamun Falls, Qld. 12, antennae; 13, dorsum; 14, venter.

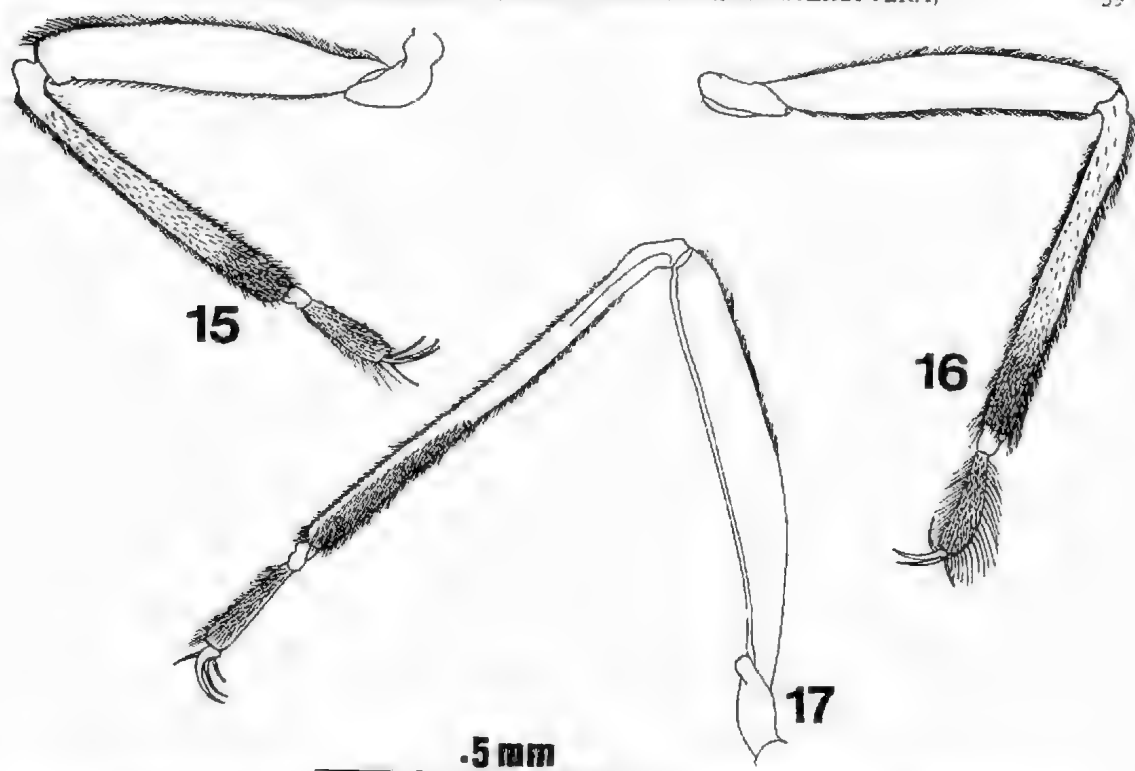
specimens. The first with 1 ♂ & 7 ♀♀ bearing a red printed Type label with *Naevogus latensis* Hale in what is presumably Hale's handwriting. The locality label (typed-photographed and reduced) reads River Torrens, Adelaide, H.M. Hale. The second card with 4 ♂♂ & 4 ♀♀ bears a red Paratype label; the other labels are identical with the first. A third card with 1 ♂ & 1 ♀ labelled Paratype is labelled in the same manner. The specimens on these three cards are all regarded as Paralectotypes and labelled accordingly.

The fourth card has 4 ♀♀ labelled Paratype from the Murray River, F.R. Zeitz. These may not be part of Hale's original type series as the collector's name is not mentioned and Hale always noted collectors

when describing or listing material not collected by himself.

Amongst additional material from Adelaide collected by Hale but not labelled Paratype are two small series of carded specimens with a typed label 'Tussocks of thin reeds growing in wet mud on banks of River Torrens 28.iii.1921'.

Material examined: Type series of *axillaris* and *latensis*; Kara Creek near Jindabyne, N.S.W., 940 m, 16.iii.1979; The Lakes Creek near Jindabyne, N.S.W., 1160 m, 16.iii.1979; Phillip Island, Vic. pool completely covered with floating vegetation, 31.iii.1985; Moggill Farm Dam near Brisbane, Qld., 6.vi.1979; Sundown National Park near Stanthorpe, farm dam, 26.iv.1985 Qld - I. Lansbury Coll. Macalister-Thomson River Junction, Vic., 19.ii.1977, Nat. Mus. Victoria Survey, M. Malipant - N.T. Museum Coll.



Figs 15-17. *Hebrus monteithi* sp. nov. Paratype ♂, Wallaman Falls, Qld. 15, fore leg; 16, middle leg; 17, hind leg.

Devonport & Launceston, Tas. Myponga Swamps, S. Aust.; Glenfield, N.S.W. - South Australian Museum, Adelaide.

***Hebrus woodwardi* sp. nov.**

FIGS 7-11, 27, 31 & 32

Holotype: Female, Paratypes 6♀ and 1♂, Queensland, Split Rock, 14 km S. of Laura, 23-26.vi.1975, G.B. Monteith in the Queensland Museum, Brisbane.

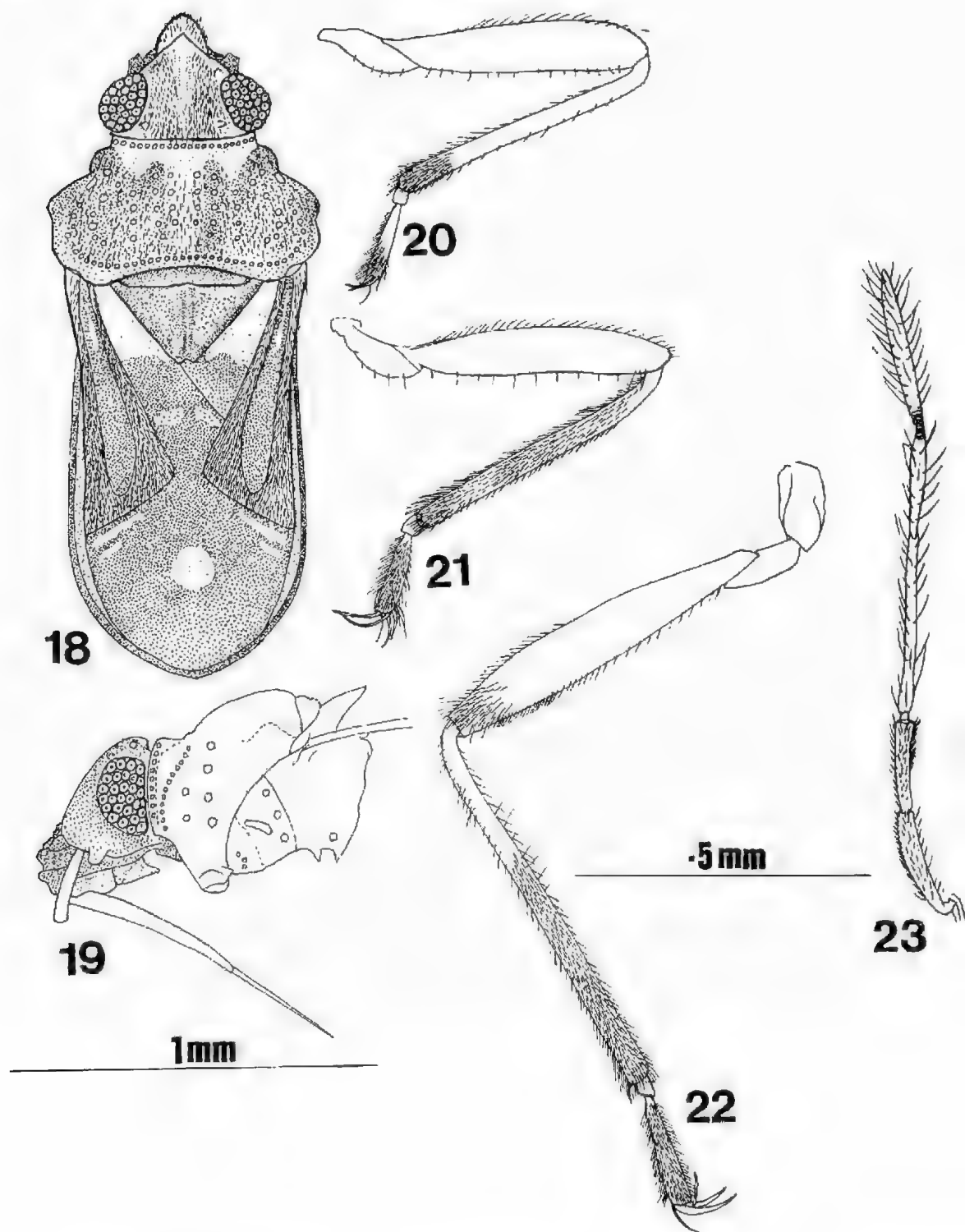
Distribution: Queensland and the Northern Territory.

Size: ♂, ♀♀ 1.68 - 1.88 mm long, width across widest part of pronotum .82 - .94 mm.

Colour: Head and pronotum reddish brown, lateral margins of vertex along inner margin of eyes and pits silvery tomentose. Antennae dark brown. Head and pronotum covered with golden spicules, some iridescent. Mesoscutellar lobe and scutellum very dark brown. Forewings; clavus and corium varying between rich reddish brown and dark brown, apical part of clavus greyish white. Apex of scutellum, clavus and corium covered with long golden hairs. Membrane smokey brown with four paler areas (Fig. 7). Lateral margins of head, bucculae, rostrum and femora pale yellow. Tibiae and tarsi slightly darker distally. Coxal insertions dark reddish brown.

Thoracic venter dark brown, sternites darker covered with fine silvery pubescence.

Structure: Interocular space about 2× maximum eye width. Median head length .66× greatest head width. Tubercles adjacent to antennal insertion small (Fig. 7). Antennae 1:2:3:4: - 7-5-10-14.5. Fourth segment subdivided by coil-like section (Fig. 8). Third segment 2× length of 2nd; 4th segment subequal to 2nd and 3rd combined. Total antennal length about half body length. Vertex with faint longitudinal furrow becoming obsolescent anteriorly. Bucculae short, usually just reaching pronotum with two depressions (Fig. 27), lower margin curved. Pronotal width 2× median length and head width across eyes. Posterior margin with two (1+1) lobes either side of scutellum. Anterior collar of pronotum sharply depressed with regular transverse row of pits. Immediately behind anterior collar, two (1+1) depressions either side of a broad longitudinal ridge which have two rows of shallow pits. Median lateral angles slightly depressed. Mesoscutellar lobe and scutellum .6× median pronotal length. Scutellum with median longitudinal ridge and lateral margins slightly raised forming two shallow depressions. Apex of scutellum truncated with minute median projections (Fig. 7).



Figs 18–23. *Hebrus nourlangiei* sp. nov. Paratype ♀, Nourlangie Rock area, N.T., 18, dorsum; 19, side view of head and pronotum; 20, fore leg; 21, middle leg; 22, hind leg; 23, antennae.

forewings obscuring abdomen, membrane reaching or overlapping end of abdomen. Rostrum with tip just reaching metasternal suture.

Front and middle femora moderately robust (Figs 9 & 10). Hind femur slightly longer than median pronotal length. Male hind legs 1.25x longer than front and middle legs, female hind legs 1.32x longer.

Male genital capsule (Figs 31 & 32).

Referred Material: Pat Creek, 11 km N. of Archer Crossing via Coen, Qld, 28-29.vi.1975, G.B. Monteith, Qld Museum, Brisbane. This ♀ differs from the type series in that the pale areas of the membrane are almost obsolescent. Red Lily Lagoon near Daly River, N.T., (13°45'S 130°42'E), 9.viii.1980, M.B. Malipatil, 1♂; Manton Reservoir on Stuart Highway, N.T., in flood debris near water edge, 9.xii.1979, M.B. Malipatil, 2♂♂, 3♀♀; Crocodile Creek, 14°29'S-131°22'E near Dorisvale, N.T., 17-18.xi.1984, M.B. Malipatil, 1♂; Lake Bennett area c. 25 km SE of Manton Dam, N.T., 29-30.xii.1979, at M.V. light, M.B. Malipatil, 1♂; U.D.P. Falls, N.T., 18-19.vii.1980, at M.V. light, M.B. Malipatil, 1♀, Northern Territory Museum Coll.

Hebrus woodwardi is very similar to *H. axillaris*; the slightly longer membrane reaching or overlapping the end of the abdomen, the relatively longer 3rd antennal segment of *H. woodwardi* and differences in the male genitalia distinguish *H. woodwardi* from *H. axillaris*.

***Hebrus monteithii* sp. nov.**

FIGS 12-17, 26, 33-35

Holotype: Male. Paratypes 7 ♂♂ (1 slide mounted) and 8 ♀♀. Qld, Wallaman Falls via Ingham, 1.x.1980, rainforest 500 m. Collected from rainforest floor by brushing twigs, G.B. Monteith in the Qld Museum, Brisbane.

Distribution: N.E. Qld.

Size: ♂♂, ♀♀ 1.9 - 2 mm long, width across widest part of pronotum .77 - .84 mm.

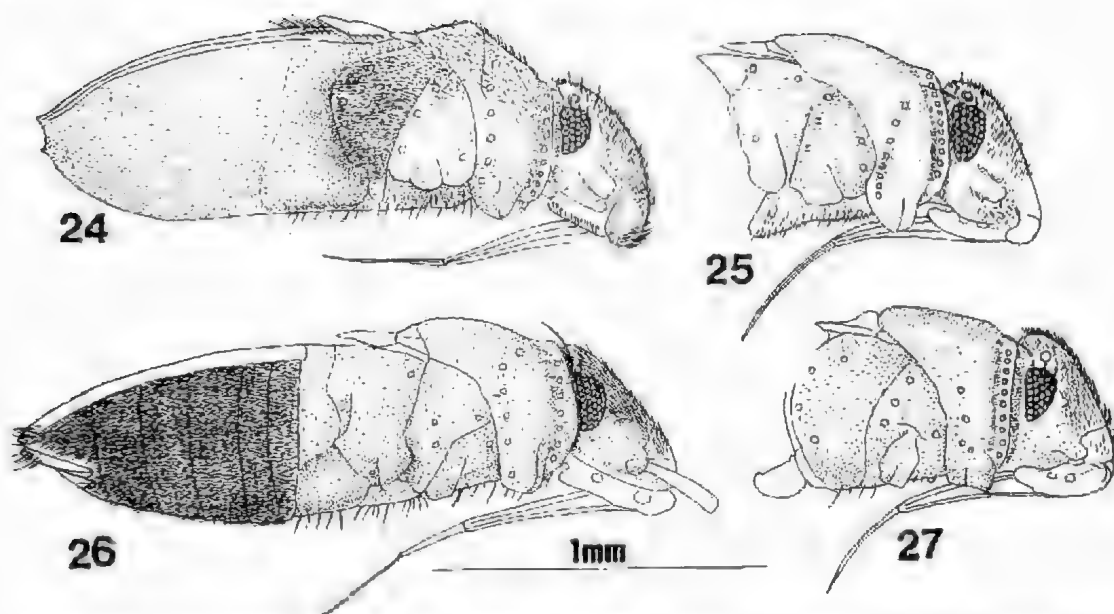
Colour: Head anteriorly black, posteriorly dark reddish brown, margins round eyes silvery tomentose. Pronotum dark reddish brown, humeral angles and median raised area of disc with iridescent bluish areas. Pronotum with sparse golden pubescence. Mesoscutellar lobe and scutellum black with sparse golden hairs slightly longer than those on pronotum. Forewings, clavus with elongate greyish white patches either side of scutellum. Corium and connexivum reddish brown. Clavus and corium with layer of golden pubescence slightly shorter than on visible area of connexivum. Membrane dark brown with faint brownish white blotches. Lateral margins of head, bucculae, rostrum, legs other than distal apices of femora pale yellow. Antennae dark brown. Underside of thorax dark brown to black. Sternites

shining black covered with fine silvery pubescence. *Structure:* Interocular space about 2x maximum eye width. Median head length subequal to greatest head width. Tubercles adjacent to antenniferous tubercles prominent (Fig. 13). Antennae 1:2:3:4 = 8.3-6-11-16.25. Fourth segment subdivided by coil-like section (Fig. 12). Third segment almost 2x length of 2nd and 4th subequal to 2nd & 3rd combined. Total antennal length slightly more than half length of body (.57-.58). Vertex with single median longitudinal furrow, difficult to see as this part of vertex densely pilose. Bucculae prominent, almost or reaching pronotum with two conspicuous circular depressions, free end rounded, ventral margin slightly sinuate (Fig. 26). Pronotal width varying between 1.7-1.96x median pronotal length and width of head across eyes. Anterior collar of pronotum narrow with transverse row of small circular pits. Anterior lateral margins straight, medially with prominent depressions. Pronotal disc elevated posterior of parallel anterior part of disc. Humeral lateral angles depressed. Posterior lateral margins emarginate, hind margin evenly curved. Mesoscutellar lobe and scutellum about half median pronotal length. Scutellum with two shallow depressions either side of median ridge. Lateral margins not conspicuously raised. Lateral margins and apex with minute iridescent spicules. Forewings small, much of connexivum exposed, membrane not reaching end of abdomen, membrane of male shorter than that of female. Connexivum shining, Rostral groove very conspicuous, rostrum almost reaching posterior margin of metasternum.

Front and middle legs similar (Figs 15 & 16) hind legs longer (Fig. 17). Hind femur 1.4 - 1.5x longer than median pronotal length. Male hind legs 1.27x longer than front and middle legs and 1.37x longer in females.

Male genitalia: Viewed dorsally, tips of symmetrical parameres extending beyond end of abdomen. Proctiger hairy. Parameres elongate, very pilose and much longer than pygophore (genital capsule) at rest and clearly visible *in situ* in undissected males (Fig. 33). Female genitalia (Figs 34 & 35) conforms to general hebrid pattern.

This species differs from all known Australian hebrids; the short membrane, large tubercles adjacent to antenniferous tubercles and prominent parameres clearly distinguish *H. monteithii* from other species. There is some similarity between *H. monteithii* and two species from the Philippine Islands, *Hebrus drakei* and *H. harrisi* Porter both described from Muntalban, Rizal Province. Both of these species have prominent elongate parameres extending beyond genital capsule. Porter does not state if the parameres are visible dorsally.



Figs 24–27. *Merragata* and *Hebrus* side view 24, *Merragata hackeri* Hungerford, Sundown N.P., Qld; *Hebrus axillaris* Horváth, Phillip Is. Vic; 26, *Hebrus munitzhi* sp. nov.; 27, *Hebrus woodwardi* sp. nov.

***Hebrus nourlangiei* sp. nov.**

FIGS 18–23

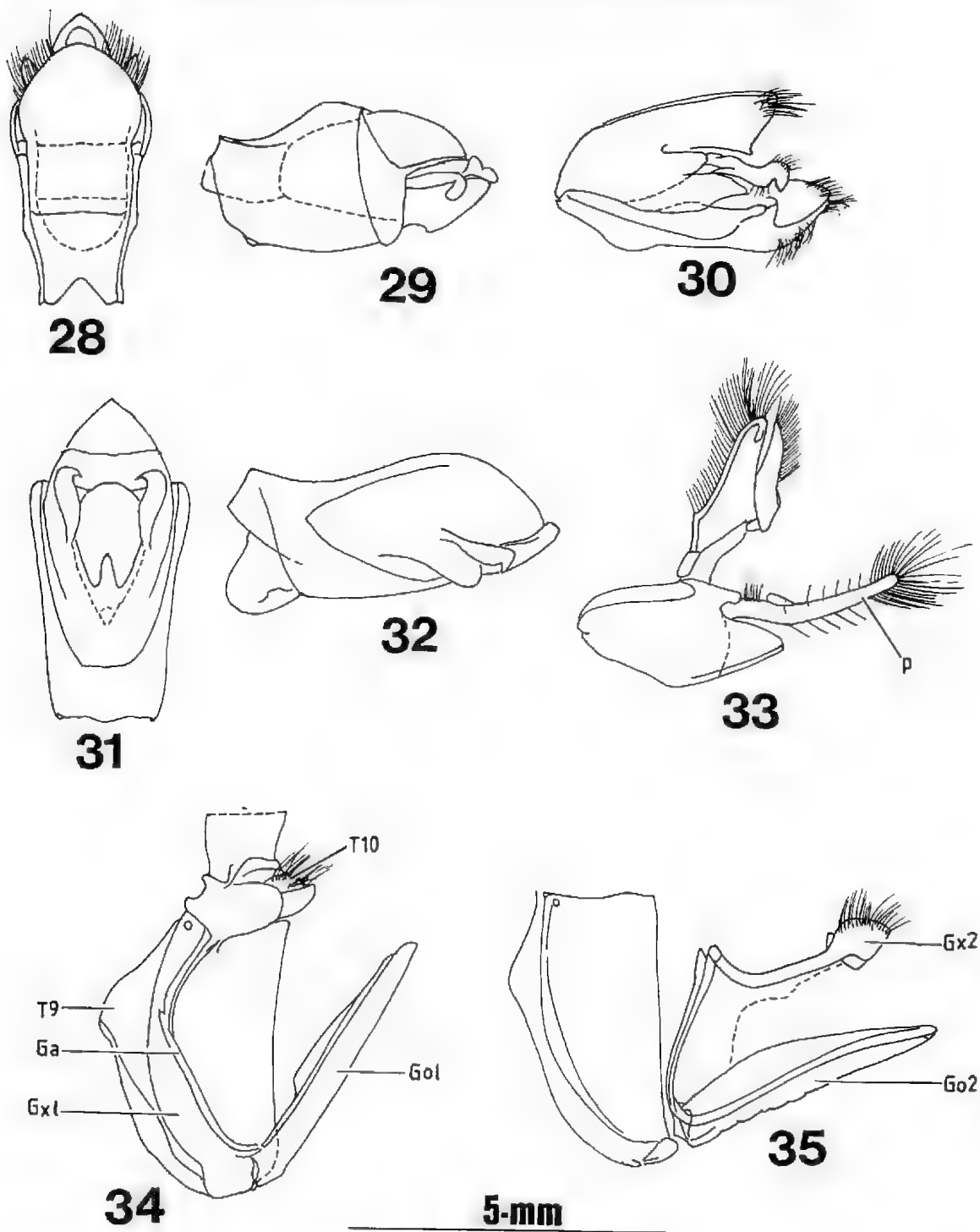
Holotype: Female, Paratypes 1♂ and 1♀, Northern Territory, Kakadu National Park, Nourlangie Rock area, from water seepage, 27.iii.1980, M.B. Malipatil, N.T. Museum Coll.

Distribution: Northern Territory.

Size: ♂ ♀ 1.7–1.8 mm long, width across widest part of pronotum .7 mm.

Colour: Head dark velvety reddish brown. Margins round eyes broadly silvery tomentose. Eyes and ocelli paler than dark areas of vertex. Antennae dark yellowish brown. Inner anterior margin of pronotum with pale orange brown trilobed zone. Outer margins and remainder of pronotum dark velvety reddish brown. Head and pronotum with minute iridescent spicules, longer hairs also iridescent. Mesoscutellar lobe and scutellum same colour as posterior margin of pronotum. Scutellum fringed with short golden hairs. Clavus with large greyish white are a reaching apex of scutellum. Corial cell slightly paler anteriorly with long yellow hairs. Membrane smokey brown with four faint greyish white blotches. Connexivum yellowish brown. Underside of head and bucculae pale yellow. Pro, meso and metasternum reddish brown. Coxal insertions pale yellow. Rostrum and legs pale yellow with upper distal apices of femora darker. Sternites dark reddish brown shining with adpressed golden hairs.

Structure: Interocular space slightly less than 2x maximum eye width. Median head length just over .66x greatest head width. Vertex strongly raised above eyes. Two (1+1) fine longitudinal furrows which converge posterior of line through ocelli. Margins of vertex converging in front of eyes, tip acuminate. Antenniferous tubercles each with truncate projection. Antennae 1:2:3:4–7.5-10-15.5. Fourth segment subdivided by coil-like section (Fig. 23). Third segment 2x length 2nd, 4th equal to combined lengths of 2nd & 3rd segments. Antennae just over half length of body. Bucculae short not reaching pronotum, with two depressions, free end bluntly acuminate. Lower margin with 'step' (Fig. 19). Anterior margin of pronotum flat and lateral margins raised. Pronotum divided by broad longitudinal depression lined with circular pits. Fore margin of raised areas deeply emarginate. Anterior lateral margins straight, humeral angles sharply produced. Posterior margin with false suture with minute shining golden brown spicules. Edges of raised lobes fringed with small pits. Lateral margins of hind margin deeply emarginate, remainder of pronotum margin evenly rounded. Dense pilosity of pronotum makes circular 'pits' rather difficult to see. Pronotal width 2.1x greater than median length, 1.8x width of head across eyes. Mesoscutellar lobe and scutellum .66x median pronotal length. Scutellum depressed with lateral margins and faint median keel forming two shallow



Figs 28-35. Hebrid ♂ & ♀ genitalia. 28 & 29 *Merragata hackeri*, 28, genital capsule; 29, *ibid* side view; 30, *Hebrus axillaris* Horváth genital capsule side view; 31 & 32 *Hebrus woodwardi* sp. nov. 31, dorsal view; 32, *ibid* side view; 33, *Hebrus monteithi* sp. nov. ♂ genital capsule, side view; 34 & 35 ♀ genitalia *H. monteithi* sp. nov. Terminology p paramere; Ga gonangulum; Gol, Go2 first and second gonapophyses; Gx1, Gx2 first and second gonocoxae; T9 T10 abdominal terga 9 & 10.

depressions, apex of scutellum bifurcate (Fig. 18). Forewings well developed, membrane almost reaching end of abdomen. Rostrum almost reaching posterior margin of metasternum.

Front and middle legs similar (Figs 20 & 21). Hind legs $1.38\times$ longer than front and middle legs. Hind femur $1.68\times$ longer than median pronotal length (Fig. 22).

Single male specimen too damaged to figure genitalia. Head and thorax detached from remnants of abdomen.

Referred Material: A female collected from Koongara Creek, (a few Km from Nourlangie Rock) 8-10.v.1979 Coll. I. Lansbury appears to be identical with *H. nourlangiei*. Koongara Creek is a series of sluggish rocky pools joined by a shaded narrow creek.

Hebrus nourlangiei is immediately recognisable from other Australian species by the bifurcate apex of the scutellum and narrow interocular distance.

Merragata hackeri Hungerford

FIGS 24, 28-29, 36-44

Merragata hackeri Hungerford, 1934, pp. 70-71

Type specimens: Holotype ♂, allotype ♀ and some Paratypes, Qld, Brisbane, December, 1932. H. Hacker; Snow Entomological Collections, University of Kansas. Additional Paratypes (same data), British Museum (Natural History) and South Australian Museum, Adelaide.

Distribution: Vic., Qld and N.T.

Size: ♂♂, ♀♀, 1.47 - 1.8 mm long, width across widest part of pronotum .77 - .9 mm.

Colour: Dorsally pale yellowish brown, elytra milky white adjacent to scutellum, sometimes slightly darker across membrane. Mesoscutellar lobe and scutellum dark brown, ridges on scutellum same colour as pronotum. Head, pronotum and lateral margins of elytra with long pale yellowish hairs. Underside of head and bucculae same colour as dorsal aspect. Prosternum dark yellowish brown. Meso and metasternum varying between reddish brown and black distally. Sternites black covered with long pale golden hairs. Legs pale yellow, distal apices of tibiae and tarsi narrowly annulated dark brown. Antennae yellowish brown, 4th segment black, 3rd segment sometimes also black.

Structure: Interocular space $3\times$ or more maximum eye width. Median head length .64 - .78 \times median head width. Vertex with two (1+1) faint longitudinal furrows converging between ocelli. Posterior margin of head raised with ocelli strongly protuberant and black. Head covered with fine whitish pubescence, shorter ventrally. Antennae 1:2:3:4: - 4.6-4.75 - 3.5-5.5, all segments covered with fine hairs (Fig. 38). Bucculae short, not reaching pronotum, lower margin appearing slightly curved/sinuate, free end

angular, medianly with large depression (Fig. 24). Pronotal width $2\times$ median length and head width across eyes. Anterior collar narrow with transverse row of pits. Anterior lobe with two (1+1) deeply slightly diverging depressions with a median longitudinal depression consisting of coalescing pits, each with fine silvery tomentose margins between. Anterior lateral margins more or less straight, shining without depressions. Pronotal humeral angles depressed, remainder of disc slightly raised with scattered pits. Posterior margin convex, medianly slightly emarginate around mesoscutellar lobe (Fig. 36). Scutellum and mesoscutellar lobe less than half median pronotal length (.41). Scutellum slightly wider than mesoscutellar lobe. Basal lateral margins raised curving towards apex with two (1+1) pits basally, median carina short. Hemelytral venation typical hebrid. Connexivum visible laterally, membrane overlapping end of abdomen. Venation heavily chitinated, usually same colour as pronotum. Anterior part of elytra covered with long fine hairs same colour as background. Abdominal ridges curved, converging slightly distally. Tergites black and shining. Rostrum short not reaching distal margin of metasternum.

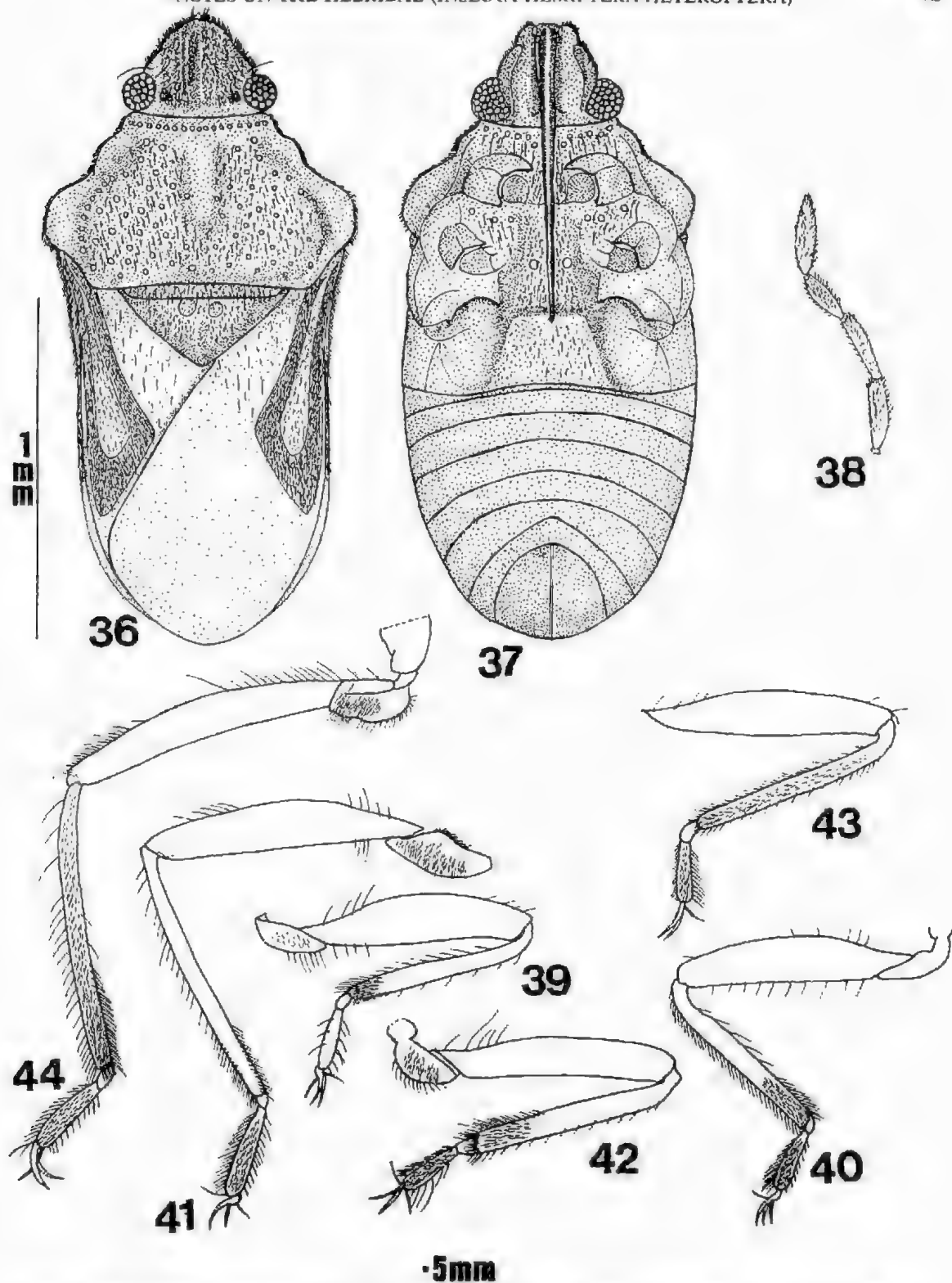
Fore coxae close together. Prosternum and collar with scattered large pits. Middle coxae wider apart, mesosternum with two (1+1) longitudinal ridges covered with dense hairs distally. Hind coxae slightly wider apart, mesosternal ridge continued onto metasternum diverging posteriorly. Sternites covered in uniform white hairs. Pro and mesopleura with scattered large pits (Fig. 37). Front and middle legs only differing slightly between sexes (Figs 39 & 40 ♂; 42 & 43 ♀). Hind legs longer, hind femora $1.25 - 1.3\times$ longer than median pronotal length. Male hind legs $1.33\times$ longer than front and middle legs (Fig. 41) and $1.22 - 1.3\times$ in females (Fig. 44).

Male genital capsule (Figs 28 & 29).

Material examined: Brisbane, Moggill Farm Dam, 6.vi.1979, Qld; Sundown National Park, in marginal grasses around farm dam, 6.iv.1985 Qld; Sundown National Park, Severn River, 6.iv.1985, Qld; Phillip Island, 31.iii.1985, Vic. found on densely overgrown pool with *Hebrus axillaris*; Ellery Gorge near Alice Springs, N.T., 28.iv.1979, I. Lansbury Coll. Tallandoou Lagoon, National Museum Victoria, Dartmouth Invertebrate Survey Vic. 3.ii.1975, M.B. Malipatil; N.M.V. Survey, Macallister Thomson River Junction Swamp Vic. 3.vii.1979, M.B. Malipatil; Red Lily Lagoon near Daly River N.T. 13°45'S-130°42'E, 5.viii.1980, M.B. Malipatil; Limestone Gorge, N.T. 16°02'S-130°23'E, 23-26.vi.1986 (Operation Kaleigh) M.B. Malipatil, N.T. Museum Coll.

Acknowledgments

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Figs 36-44. *Merragata haekeri* Hungerford, Sundown N.P., Qld. 36, dorsum; 37, ventral; 38; antennae; 39-41 ♂, 39, fore leg; 40, middle leg; 41, hind leg; 42-44 ♀, 42, fore leg; 43, middle leg; 44, hind leg.

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A NEW GENUS AND SPECIES OF SCORPION FROM SOUTH AUSTRALIA (BUTHIDAE: BUTHINAE)

*BY N. A. LOCKET**

Summary

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Introduction

The early work on Australian scorpions, and notably that of Keyserling (1885), was consolidated by Kraepelin (1899). This work was reviewed by Glauert (1925), the paper serving as a basis for the Buthidae for the monograph of Koch (1977) on all Australo-Papuan scorpions. Koch reduced to three the ten species of *Lychas*, and synonymised the two *Isometroides* described by Glauert (1925).

Examination of buthid scorpions in the collection of the South Australian Museum and the author's collection has revealed some specimens which do not fit the published descriptions. Living examples of this new taxon have since been obtained, allowing the following description to be supplemented by information on habitat and behaviour.

Materials and Methods

The holotype, allotype and ten paratypes are in the collection of the South Australian Museum, Adelaide (SAM). Referred material includes eight specimens in the South Australian Museum and nine in the author's collection. Terminology follows Hjelle (in press); that for trichobothria follows Vachon (1973). Measurements were made with an eyepiece micrometer, and are expressed as mean \pm standard deviation. Figures were drawn using a camera lucida, with details added freehand, except for Fig. 3. In this composite figure the posture was drawn from a negative of a photographed living specimen, projected onto a baseboard, and detail added freehand from preserved specimens. Measurements of width of lamina and length of

tooth of pectines were made as in Fig. 7c. The right hemispermatophores were drawn, following Koch (1977), except that each was drawn from two positions, with the lamina perpendicular to the page, and rotated 90° to the right. Live specimens have been observed by U.V. light, in the field (Stahnke 1972), and later kept for several months in the laboratory in containers of slightly damp sand containing a flat stone as shelter; the animals were fed mealworms at intervals.

Systematics

Family: Buthidae Simon, 1879

Subfamily: Buthinae Kraepelin, 1899

Australobuthus gen. et sp. nov.

Type species: *Australobuthus xerolimniorum* sp. nov.

Diagnostic definition: Carapace without definite keels. Median eyes in anterior half of carapace. Three subequal lateral eyes. Tergites I-VI with poorly developed median keel, no lateral keels. Pretergites of I-VI with distinctly wavy posterior margin. Pectines long, reaching to or beyond trochantero-femoral joint of fourth leg. 30-36 teeth. Metasomal segments stout, squat, of almost equal width, all keeled. Vesicle small, somewhat elongate, not keeled. Aculeus stout, clearly distinct from vesicle, definite subaculear tooth absent, but rudimentary subaculear tubercle in some specimens (mostly juveniles). Chelicerae with single ventral tooth on fixed finger. Pedipalp: Femoral trichobothria, four dorsal and five internal. β pattern, d4 close to anterosuperior keel, d1, d3 and d4 forming a right angle. Patella with 13 trichobothria. Hand small, rounded, keels absent. Fixed fingers with six, movable with seven slightly imbricated rows of fine

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even denticles, extending full length of fingers, flanked by internal and external accessory teeth. One or two accessory teeth proximal to terminal tooth and medial to distal row of denticles. Twelve trichobothria.

Etymology: The generic name: *Australobuthus*, refers to the southerly distribution of this buthid scorpion.

Comparison with other genera

The new genus shares a number of characters with *Isometroides* and *Lychas*, but differs from both in significant features. The metasomal segments are all keeled like those of *Lychas*, though the arrangement of the keels is different. The fifth metasomal segment of *Isometroides* is not keeled, but smooth and markedly punctate. The presence of a definite subacicular tooth, lacking in the new genus, is a diagnostic character of *Lychas*. *Isometroides* lacks a subacicular tooth; the vesicle and aculeus in that genus merge without clear distinction and are more elongated than in the new genus. The vesicle of *Australobuthus* is markedly smaller than in *Lychas*. The pectines are substantially longer, and with more teeth, than in either *Lychas* or *Isometroides*. These differences justify the erection of a new genus.

Australobuthus xerolimniorum sp. nov.

FIGS 1-14

Holotype: SAM N1988568. Adult male. Under log, Lake Hart shore, S. Aust. xii. 1984. B. Guerin.

Allotype: SAM N1988569. Adult female. On surface, Lake Gilles, S. Aust. 32° 41' S, 136° 54' E. 12.x.1980. P. Hudson.

Paratypes: (All paratypes are adult. Several juveniles are included in the referred material.) SAM N1988 570-72. Under stones on salt, Price Peninsula, Lake Eyre. 7.xi.1955. E.J. Giles 2 ♀♀, 1 ♂; SAM N1988 573. Everard Ranges. x.xi. 1970. G.E. Gross, E.G. Matthews. ♀; SAM N1988 574 In lycosid burrow, Lake Gilles, (32° 43' 06" S, 136° 48' 14" E), 26.xii.1980. P. Hudson ♂; SAM N1988 575. Lycosid burrow, Lake Gilles. I.iii.1980, P. Hudson ♂; SAM N1988 576. Lake Gairdner, surface. viii.1987. P. Hudson ♀; SAM 1988 577-579. Lake Gairdner, surface. 5.i.1989. P. Hudson ♀♀.

Diagnosis: As for the genus with the following additions. Small (35-42 mm total length, adult). Pale fawn, due to lack of subcuticular pigment except around eyes. Carapace and tergites I-VI finely granular or shagreened. Median eyes large, diameter \bar{x} = 0.131, (10.18. n = 21), \bar{x} interocular distance

Pectine tooth count 30-36, \bar{x} = 33, \pm 1.8 (n = 41), pectinal teeth uniform.

Description: Measurements of holotype and allotype in Table 1.

Length. 40.5 mm. Colour. Metasoma and extremities very pale fawn, transilluminate freely (Fig. 1). Black pigment in and around median and lateral eyes, otherwise no subcuticular pigmentation (Fig. 2). Dorsal surface of mesosoma appears striped, due to pale borders of tergites showing up against dark coloured viscera. Extremities show little dark sclerotisation, but cheliceral teeth and teeth along the fingers dark. Aculeus and pedal claws, but not tibial nor pedal spurs, darkly sclerotised.

Carapace (Figs 3, 4). Almost straight finely granular anterior border bearing a few small setae, frontal notch hardly distinguishable, anterolateral angles rounded. Posterior margin almost straight, without setae. Surface finely granular or shagreened, granularity most prominent in anterior half. Definite keels absent. Interocular area smooth. Median groove continues over ocular tubercle, which rises about half one median eye diameter above carapace line. Supraciliary ridges finely granular, but not continued as keels. Median eyes large, 0.12 \times carapace length, diameter 0.84 \times interocular distance. Posterior border of eye in front of midpoint of carapace. Three lateral eyes subequal, corneas contiguous, half their own diameter from carapace margin. Pigment deep to eyes contiguous.

Tergites of first six mesosomal segments almost smooth or finely shagreened, posterior edges smooth, with fine granules. Poorly developed smooth median keel but no lateral keels. Smooth pretergite bounded posteriorly by distinctly wavy margin (Fig. 5).

Seventh mesosomal tergite shagreened, with low central ridge only in anterior two-thirds of segment, but two well-developed lateral pairs of finely denticulate keels present in posterior two-thirds. Posterior border smooth, with fine granules, dorsal and ventral lateral borders rounded, with fine denticulation.

Sternites (Fig. 6). Smooth, shiny, with fine setae along posterior border. Spiracles small, slightly concave posteriorly. Seventh mesosomal sternite smooth, shiny, with rounded posterior border. Lateral keels finely granular, prominent in posterior two-thirds of segment, median keels less developed, in posterior half.

Sternum (Fig. 4b). Subtriangular, small median eminence anteriorly with pit with densely sclerotised but pale walls directly posterior to it, and deep pit in posterior part of sternum. Genital operculum divided in all specimens.



Fig. 1. Above, *Australobuthus xerolimmiorum* gen. et sp. nov., adult male, Lake Gairdner; below, adult female, Lake Gairdner. Scale bar = 5mm.

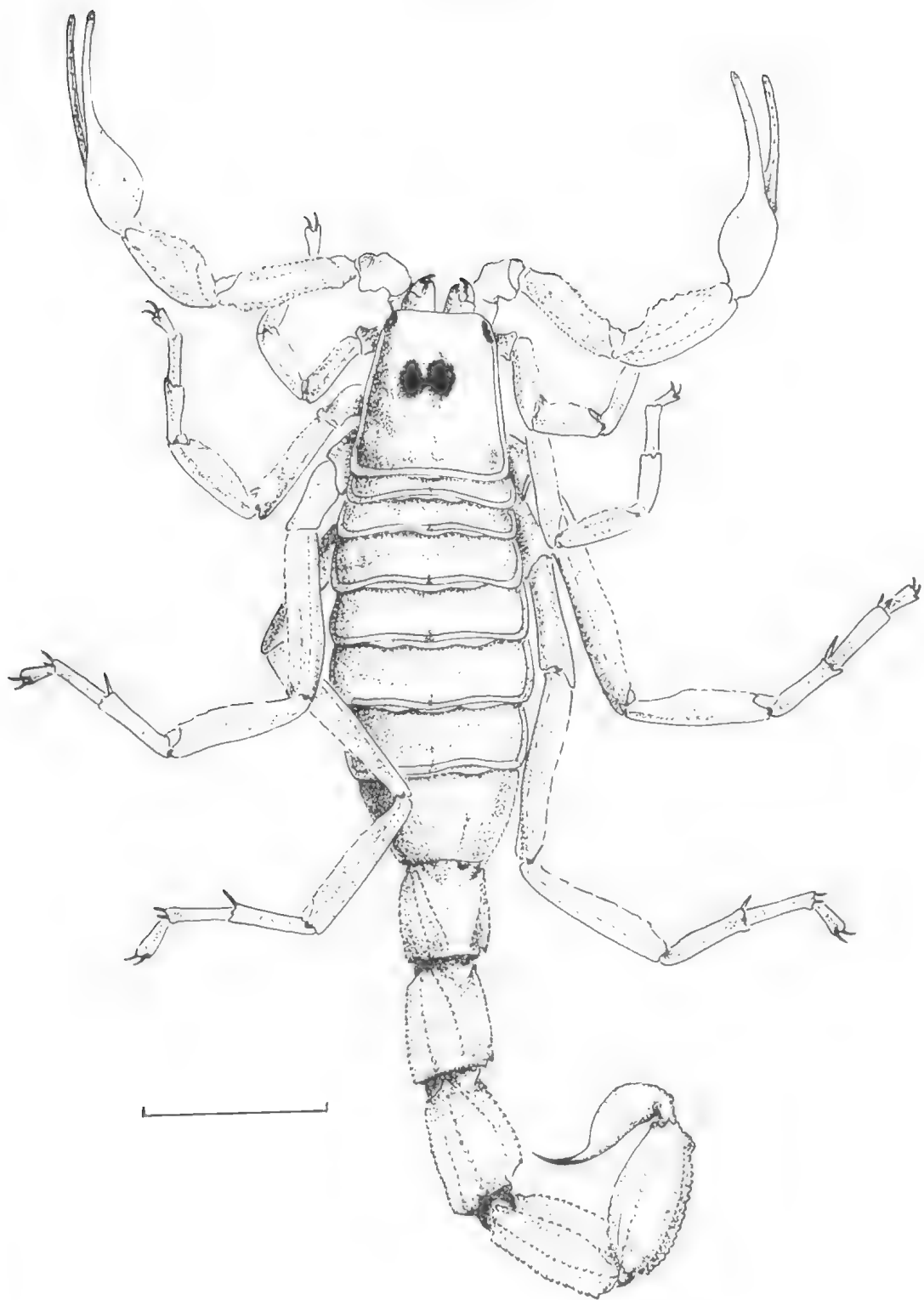


Fig. 2. *Australobuthus xerolimniorum* gen. et sp. nov., male. Scale bar = 5mm.

Pectines (Fig. 7). Very long, 32, 33 teeth, extending well beyond trochantero-femoral joint of fourth leg and close to rear border of sternite III, covering the spiracle of that sternite.

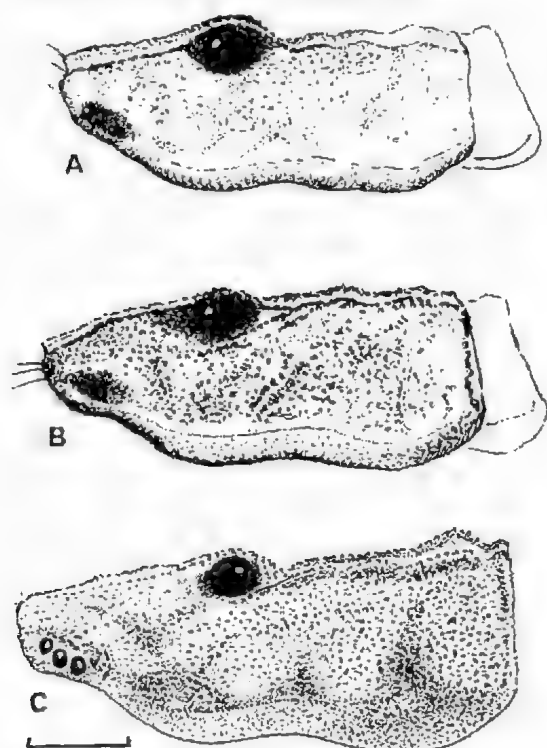


Fig. 3. Carapace, lateral view. A, *Australobuthus xerolimniorum* sp. nov. B, *Lychas alexandrinus*. C, *Isometroides vesus*. Scale bar = 1mm.

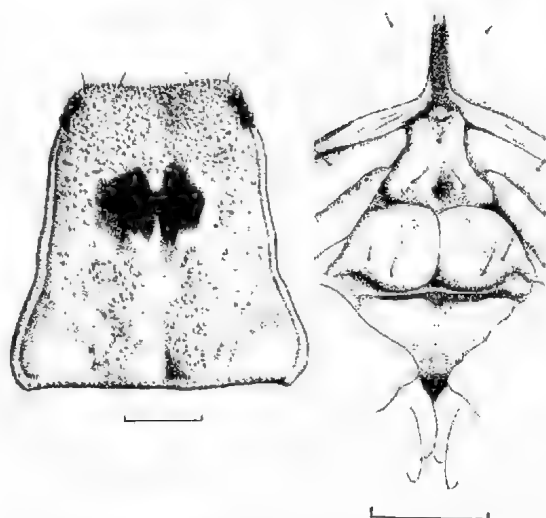
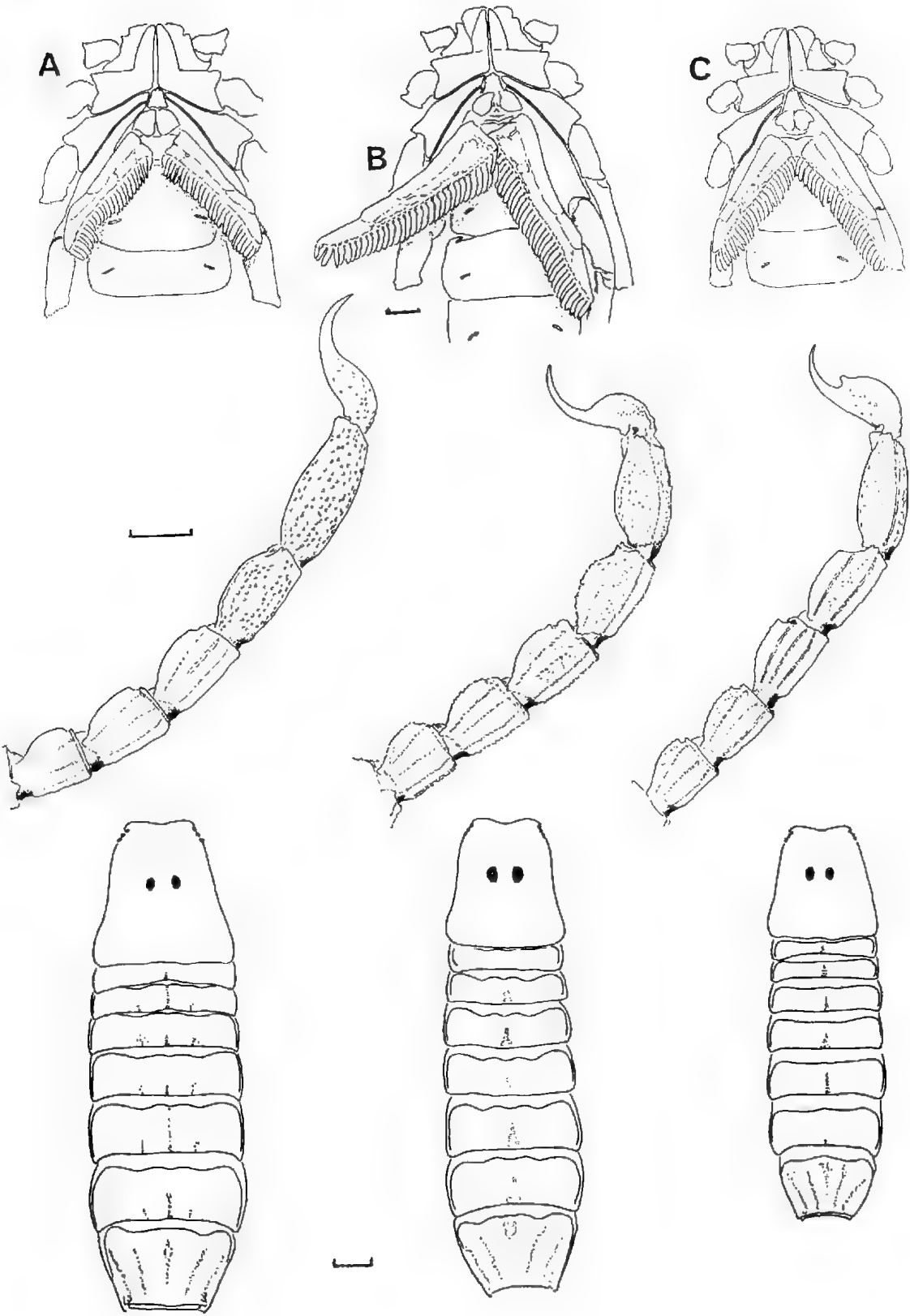


Fig. 4. *Australobuthus xerolimniorum* gen. et sp. nov. A. Carapace. B. Sternum and genital operculum. Scale bars = 1mm.

Metasoma (Fig. 8a). Length of metasoma, 0.55 × total length. First and fifth segments equally wide, slightly wider than second, third and fourth, which are themselves of equal width. Dorsal surfaces of metasomal segments smooth, lateral surfaces mostly smooth, not shiny, with few fine granules. First four segments squat, intercarinal surfaces smooth, not shiny. First segment with ten granular keels, terminal tooth of these hardly enlarged. Ventromedial keels entire, equidistant from each other as from ventrolateral. Lateral keel

TABLE 1. Measurements in mm, of *Australobuthus xerolimniorum*, gen. et sp. nov. Holotype male, allotype female.

	♂	♀	♂	♀	♂	♀
Total length	40.5	39.5				
Carapace	L 4.6	4.3	W 4.5	4.3		
Mesosoma	L 12.0	13.6				
Metasoma I	L 3.0	2.6	W 2.6	2.6	H 2.3	2.2
II	L 3.3	3.0	W 2.6	2.4	H 2.3	2.2
III	L 3.4	3.0	W 2.6	2.4	H 2.3	2.2
IV	L 4.1	3.5	W 2.5	2.5	H 2.2	2.1
V	L 4.3	3.9	W 2.6	2.6	H 2.1	1.8
Telson	L 4.2	4.1				
Vesicle	L 2.4	2.2	W 1.4	1.4	H 1.3	1.1
Aculeus	L 1.9	1.9				
Pedipalp; femur	L 3.5	3.2	W 1.0	1.0	H 0.7	0.7
Patella	L 3.8	3.4	W 1.4	1.4	H 1.1	1.1
Hand	L 6.0	5.6	W 1.3	1.1	H 1.4	1.2
Movable finger	L 4.1	3.8				
Fixed finger	L 3.7	3.4				
Chelicera:						
Movable finger	L 1.0	1.1				
Fixed finger	L 0.5	0.6				
Pectine	L 6.8	5.8				
Teeth (max.)	L 1.0	0.9				
Pectine tooth count	34,35	31,32				



present on posterior 2/3 of segment. Second and third segments similar. Fourth segment with eight keels, lacking lateral keel. Fifth segment stout, with four definite keels and coarsely granular, poorly defined, complete, not bifurcating ventromedian keel. Ventrolateral keel denticulate, dorsolateral granular, less prominent. Few intercarinal granules. Median dorsal furrow smooth, somewhat shiny.

Telson. Vesicle small, rather elongate. (Width of vesicle/width of metasomal segment V; 0.55). Smooth and shiny with few scattered small granules, no keels. No subaculear spur but minimal subaculear tubercle in small specimens. Aculeus stout, sharply curved, terminal half dark due to sclerotisation.

Chelieerae (Fig. 9). Manus and fingers smooth, pale; teeth dark (due to sclerotisation, not subjacent pigment), without secondary serrations, single ventral tooth on fixed finger, pattern as shown in figure.

Pedipalp (Fig. 10). Femur; dorsal and posterior surfaces finely granular, not shiny. Anterior surface smooth with scattered fine granules and irregular line of large granules and denticles, some bearing strong setae. Anteroventral keel of small regular granules, anterodorsal keel of small regular granules without setae. Posterodorsal and posteroventral keels of small, less regular granules, some bearing setae, particularly at the ends.

Patella; smoothly curved posterior border, smooth or finely shagreened surfaces, not shiny. Keels on dorsal surface weakly granular. Anterior border coarsely denticulate and granular, some teeth and granules bearing setae. Ventral surface smooth, convex.

Hand; small, rounded, no keels, smooth and shiny, bearing scattered setae. Fingers long, slender, $0.64 \times$ length of whole hand. Straight in lateral view, gently curved in dorsal view. Movable finger with eight external accessory teeth, seven internal and one terminal. Seven oblique rows of fine even teeth. Fixed finger with six-seven external accessory teeth, six internal and one terminal. Six oblique rows of fine teeth. Fixed finger with scattered fine setae, movable finger with more, particularly ventrally and at tip. Trichobothrial pattern as shown in Fig. 11.

Legs (Fig. 12). Smooth or finely shagreened on dorsal surfaces, shiny ventrally, keels low and rounded, barely granular. Single pale tibial spur on third and fourth legs, two equal pale spurs on tarsomere II of all legs. Terminal claws equal on all legs. Few stout setae on femora, stout setae on

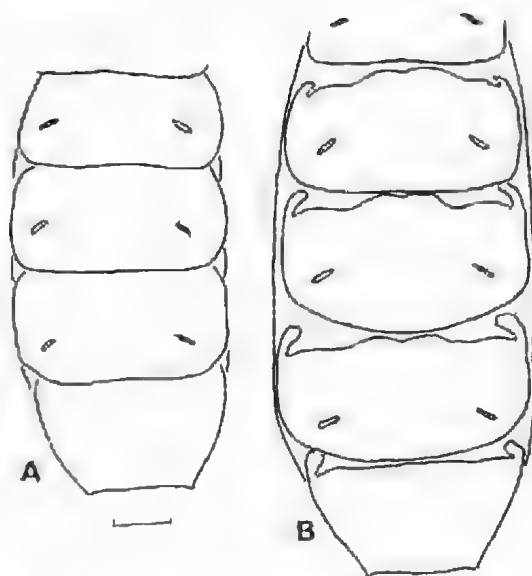


Fig. 6. *Australobuthus xerolimnium* gen. et sp. nov. Outlines of sternites showing sexual dimorphism. A, male, B, female. Scale bar = 1mm.

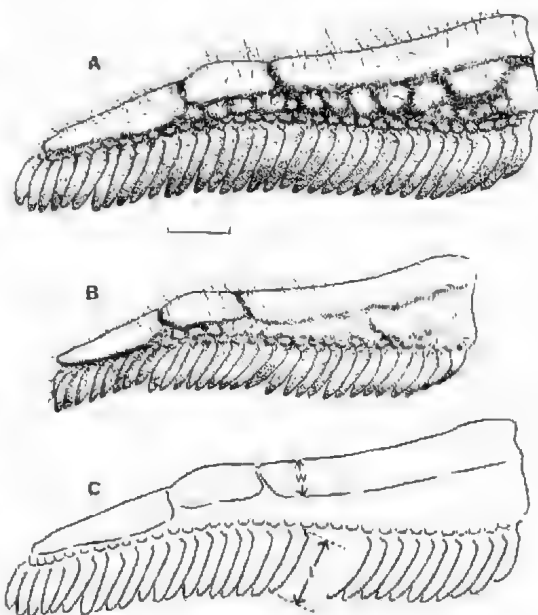
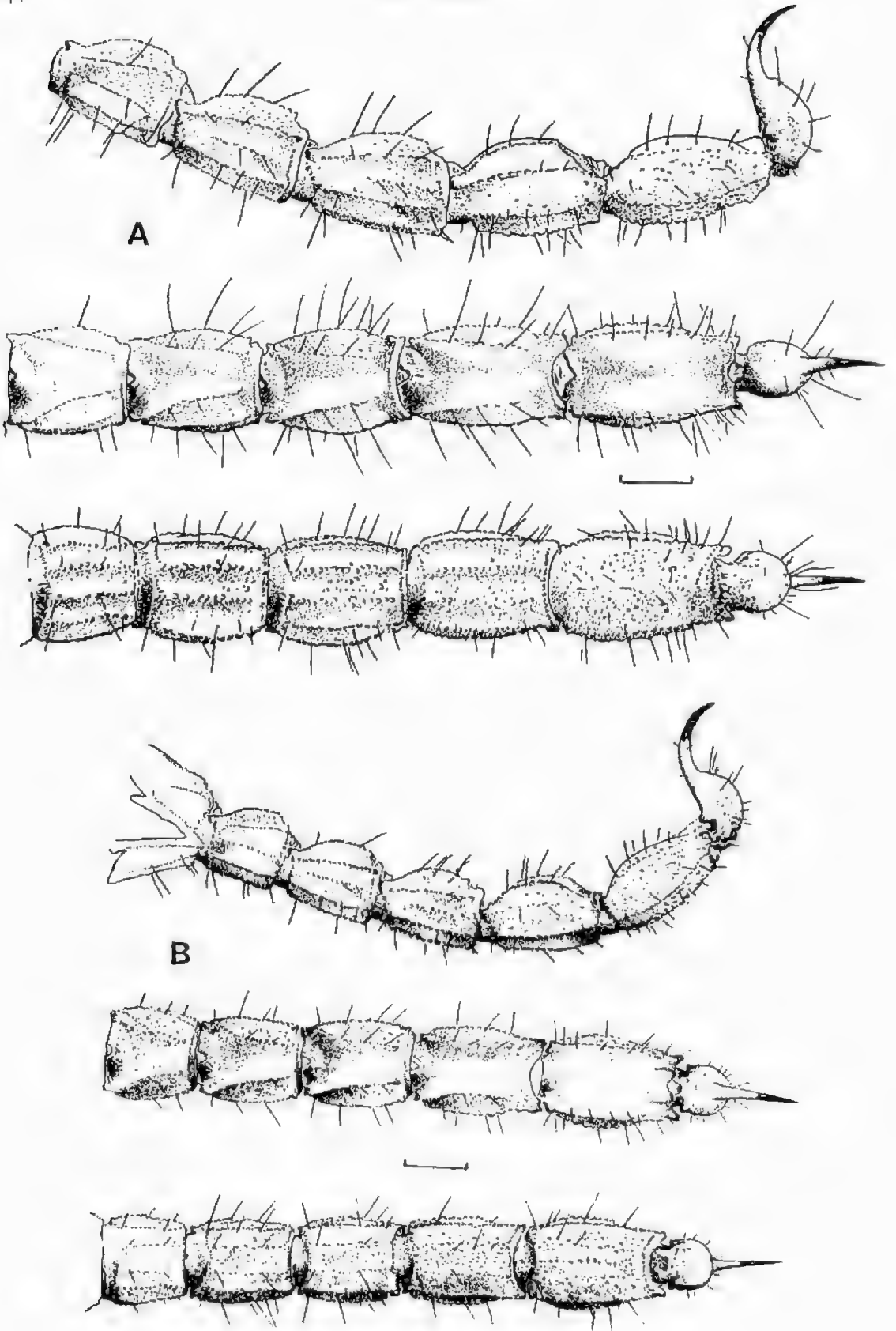


Fig. 7. *Australobuthus xerolimnium* gen. et sp. nov. Pectines, A male, B, female, C. Measurement site for width of lamina, W, and length of tooth, L. Scale bar = 1mm.

Fig. 5. Ventral views to show proportions of pectines, lateral views of metasoma and dorsal view of carapace and tergites. A, *Isometroides vesicus*, B, *Australobuthus xerolimnium*, C, *Lychas alexandrinus*. Scale bar, common to each series = 1mm.



anterior and posterior borders of patella, especially along anterior. Setae evenly distributed on tibia, and tarsomeres I and II. Those on tarsomere I mostly in two rows, on tarsomere II scattered irregularly and closely packed, not forming a comb.

Variation

No specimens show any trace of pattern; all are pale except for the eye pigmentation. The median eyes appear large in all, their diameter $= 0.09\text{--}0.14 \times$ carapace length ($n=21$, $\bar{x} = 0.125$, ± 0.015). Their diameter is $0.59\text{--}1.08 \times$ interocular distance, ($n=21$, $\bar{x} = 0.81$, ± 0.18). All but one have three lateral eyes on each side; one specimen has four on one side and three on the other. The posterior borders of the sternites are markedly convex in juveniles (and in adult females, see sexual dimorphism, below). The pectines are long in all, with tooth count 30–36 ($n=41$, $\bar{x} = 0.56 \text{ m} \pm 0.04$). None have a definite subacicular tooth, but a minimal subacicular tubercle is present in some specimens, mainly juveniles. The fingers are long in all, $0.63\text{--}0.68 \times$ hand length ($n=20$, $\bar{x} = 0.65$, ± 0.02).

Etymology: The specific name, *xerolimniorum*, is from Greek *xeros*, dry and *limne*, lake.

Sexual dimorphism: In some scorpions the sexes may be distinguished easily by differences in bodily proportions, females tending to have larger and stouter mesosomas with respect to the metasoma than males. Pectine tooth counts also may vary between sexes, males tending to have more teeth than females. Neither criterion applies in the present

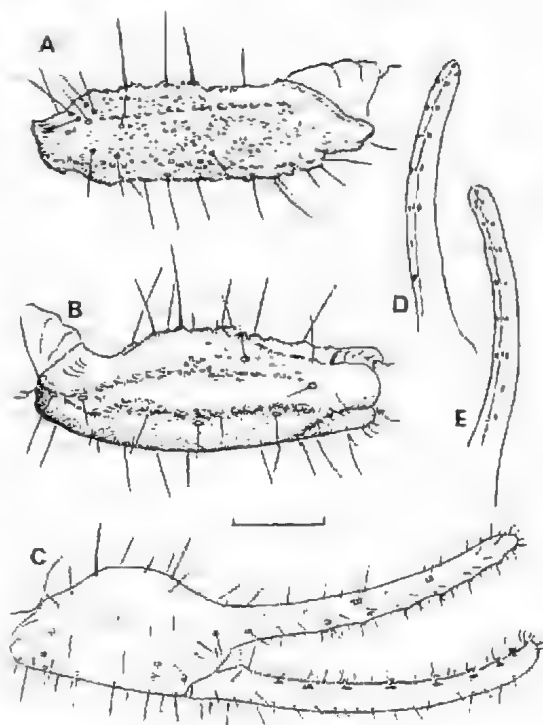


Fig. 10. *Australobuthus xerolimniorum* gen. et sp. nov. Pedipalp. A, femur, dorsal. B, patella, dorsal. C, hand, lateral. D, dentition, fixed finger. E, dentition, movable finger. Scale bar = 1mm.

case. Some specimens appear to have stout mesosomas, but this is due to distension. Comparisons of the widths of tergite III with metasomal segment V show no significant difference; nor is there a significant difference in pectine tooth counts.

The presence of hemispermaphores or embryos within the body would be clear evidence of sex, but entail dissection of the specimen and are not applicable to immature examples. Only one male of four opened contained hemispermaphores, (Fig. 13). Males have genital papillae beneath the plates of the genital operculum, but these are not visible in life. Other characters have therefore been sought which will enable the sexes to be told apart in the intact or living animal.

Though the pectine tooth counts are very similar in the two sexes, there are distinct differences in the lengths of the pectines relative to the trochanterofemoral joint of the fourth leg. In males the pectine extends well past this joint (Fig. 5), but in females it extends little if at all past the joint. There is also a difference in the proportion, width of

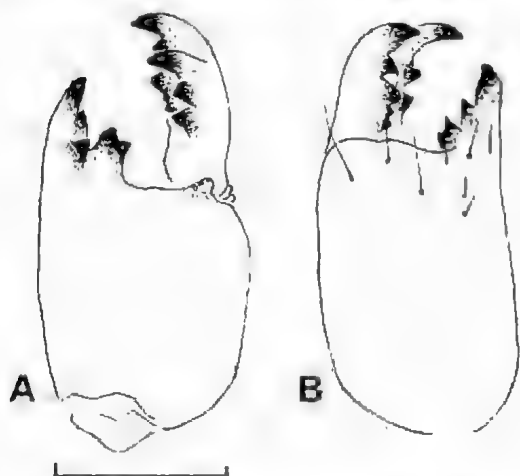


Fig. 9. *Australobuthus xerolimniorum* gen. et sp. nov. Chelicera showing dentition, dense ventral patch of setae omitted. A, ventral. B, dorsal. Scale bar = 1mm.

Fig. 8. *Australobuthus xerolimniorum* gen. et sp. nov. Lateral, dorsal and ventral views of metasoma. A, male, B, female. Scale bar = 1mm.

lamina/tooth length. (Fig. 7c). The mean of this ratio is 0.40, ± 0.03 ($n=9$), in males and 0.50, ± 0.06 ($n=6$) in females.

Another character which appears to be useful is the shape of the posterior borders of sternites 3 and 4. In males these are straight or concave, but in females they are convex (Fig. 6). This character, however, is probably unreliable in juveniles; in those examined the border of all sternites are strongly convex.

Distribution

Specimens have been recorded from Lake Eyre, Lake Hart, Lake Gairdner and Lake Gilles in South Australia. One specimen is labelled Everard Ranges; the exact locality is not specified, but was probably close to Victory Well (G.F. Gross pers. comm.). All known localities are shown in Fig. 14.

Habitat and behaviour

All but one of the thirty specimens known to date have been found on the shores or surfaces of dry

lakes in S. Aust. (B. Guerin, P. Hudson pers. comm.; pers. obs.) Some have been taken by day under logs on the salty lake surface, sometimes up to 100 m from the shore. Some of these have been in a shallow scrape under the log, but others have been dug from vertical or oblique cylindrical burrows up to 15 cm deep. Scorpions may be inhabiting a pre-existing burrow, but they are certainly capable of vigorous digging themselves, and have constructed similar burrows in captivity. Four specimens from Lake Hart were captured by the use of U.V. light at night. One of these was on the surface of the lake near a line of partly fallen fence posts, the others among sand and low vegetation on the shore. Those seen on the surface at night were walking slowly about, with the tail held over the back, but when they were allowed to move about on sand by day they ran with the tail extended behind, proving very agile.

Comparison with other species

Glauert (1925) described ten species of *Lychas* and two of *Isometroides*, but Koch (1977) reduced these

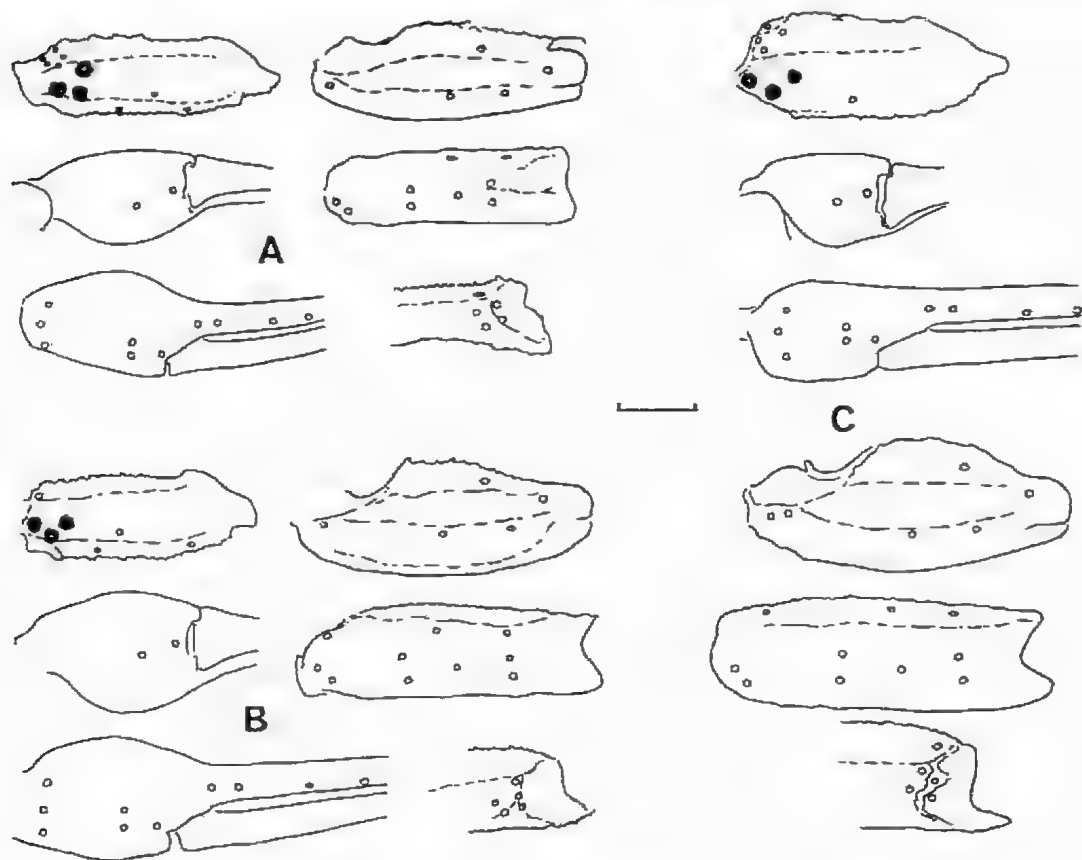


Fig. 11. Trichobothrial patterns. A, *Australobuthus xerolimniorum* sp. nov. B, *Lychas alexandrinus*. C, *Isometroides vescuus*. Scale bar = 1 mm.

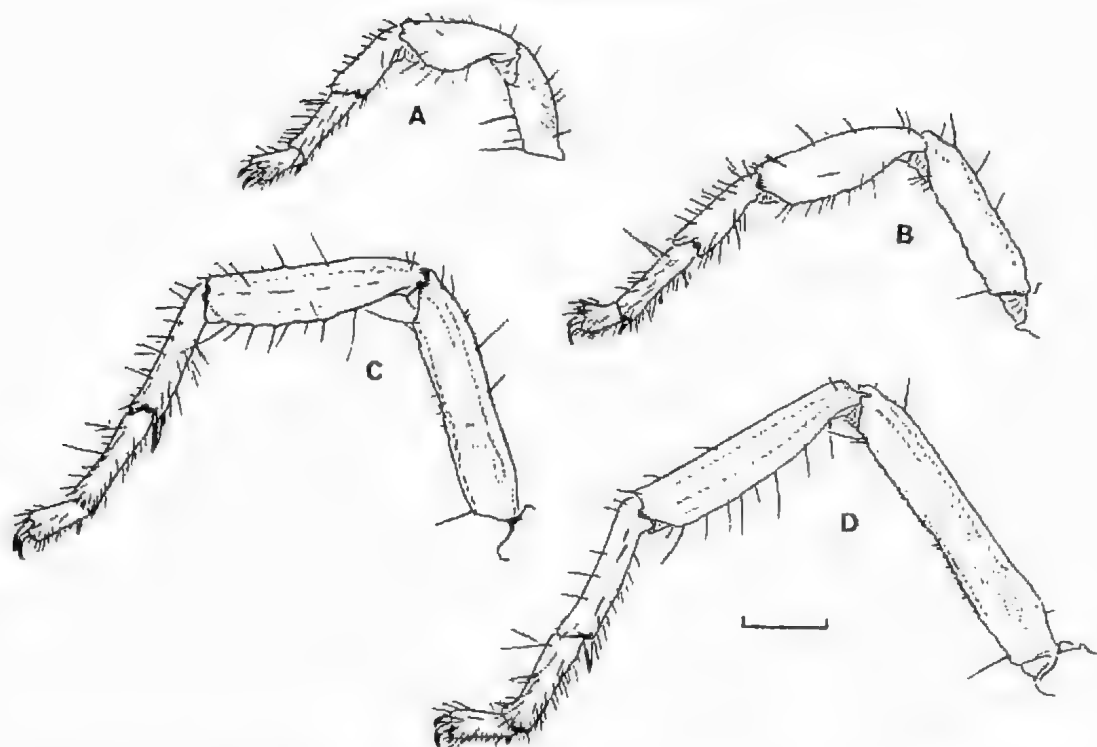


Fig. 12. *Australobuthus xerolimniorum* gen. et sp. nov. Walking legs. A-D = I-IV. Note tibial spurs on III and IV, tarsal spurs on all. Scale bar = 1mm.

to three *Lychas* and one *Isometroides*. Gläuert's work is not illustrated, but it is clear from the descriptions given, particularly the pectine tooth counts and attention given to the subaculear tooth, that neither author had before him examples of the taxon now described.

The new taxon, *Lychas alexandrinus* and *Isometroides vescus* are sympatric at Lake Hart and possibly elsewhere, and the three are now compared.

Of comparable size to *L. alexandrinus*, but smaller than a mature *I. vescus*, live specimens of *A. xerolimniorum* sp. nov. are markedly paler than both of these species. *L. alexandrinus* is usually a reddish sandy colour, with some patterning on the mesosoma, and the proximal two thirds of the fifth metasomal segment is darkly pigmented. *I. vescus* varies in colour, some specimens being variegated like *L. alexandrinus*, and others showing a uniformly dark body but pale legs. In all, however, the fifth metasomal segment and the entire telson are black or nearly so. The metasomal segments and telson of *A. xerolimniorum* sp. nov. are unpigmented.

The carapace of *A. xerolimniorum* sp. nov. is less sculptured than that of the other two species. That of *I. vescus* and *L. alexandrinus* is markedly granular, though without keels, but the carapace of

A. xerolimniorum sp. nov. is finely granular, particularly on the posterior half, or merely shagreened. The median eyes of *A. xerolimniorum* are usually larger than those of the other two (Fig. 3).

Though not previously used as a character in scorpion taxonomy, the shape of the border between the pre- and post-tergites shows a difference between the three species. This border is markedly more sinuous in *A. xerolimniorum* sp. nov. than in *L. alexandrinus*; that of *I. vescus* is intermediate in form (Fig. 5).

The pectines of *A. xerolimniorum* sp. nov. are much longer than those of either *I. vescus* or *L. alexandrinus*. In *A. xerolimniorum* sp. nov. they extend as far as, in females, or in males well beyond, the trochantero-femoral joint of the fourth leg, but in the other two they fall short of or barely reach that joint (Fig. 5). The tooth count reflects this greater length, being 30-36 in *A. xerolimniorum* sp. nov. compared with 17-29 in *L. alexandrinus* and 20-28 in *I. vescus* (Koch 1977; pers. obs.).

The form of the telson is different in the three, (Fig. 5) and, with the colour differences, enables them to be distinguished easily in the field. The vesicle of *A. xerolimniorum* sp. nov. is noticeably small, without a definite subaculear tooth. The

genus *Lychas* is characterised by a prominent subaculear tooth, and this is well shown by *L. alexandrinus*. *I. vescus* has a long telson in which the aculeus and vesicle appear continuous and there is no trace of a subaculear tooth or tubercle.

The fifth metasomal segment also differs between the three. That of *A. xerolimniorum* sp. nov. is squat, with well marked granular keels and scattered granules on the intercarinal surfaces. In *L. alexandrinus* the keels are less pronounced and the whole segment is markedly smoother than in *A. xerolimniorum* sp. nov., though it has some fine granulation, particularly on the ventral surface. *I. vescus* however shows no trace of granulation nor of keels. Rather there are numerous pits over the otherwise smooth and shiny surface. The fourth metasomal segment in *A. xerolimniorum* sp. nov. is considerably more granular than that of *L. alexandrinus* (Fig. 5) and the dorsal keel terminates in a prominent denticle.

The trichobothrial patterns of the three are shown in Fig. 11, and a small but constant difference is apparent. In *A. xerolimniorum* sp. nov. femoral trichobothria d^1 , d^3 and d^4 (filled circles in figure)

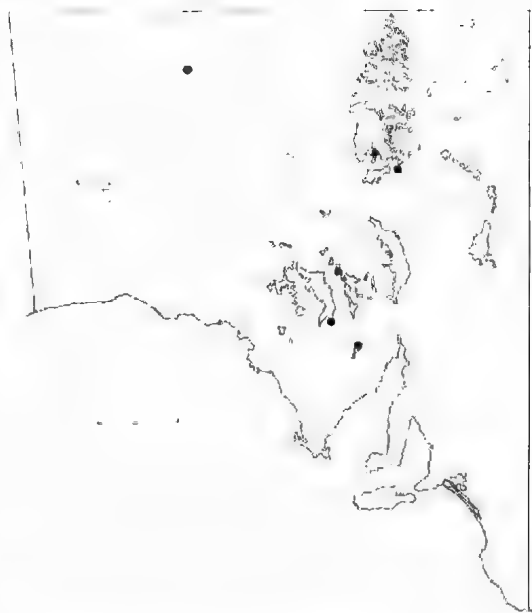


Fig. 14. Sites from which *Australobuthus xerolimniorum* gen. et sp. nov. has been collected. Scale bar = 100km.

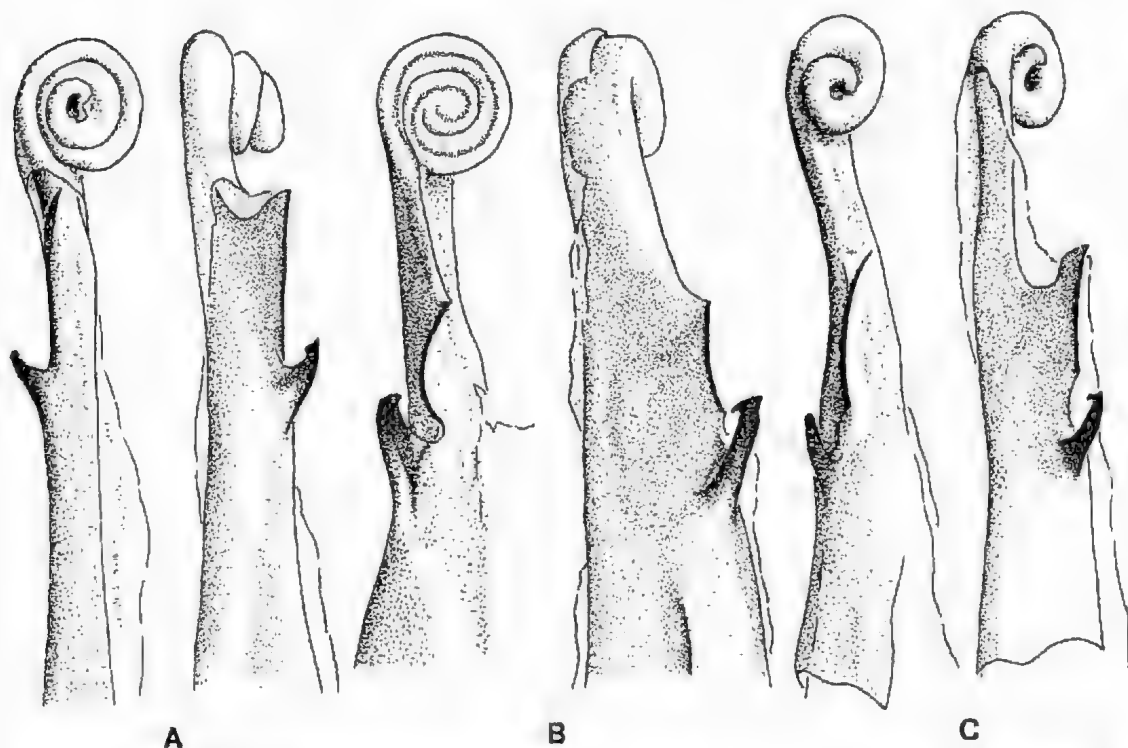


Fig. 13. Hemispermatophores. A, *Lychas alexandrinus*. B, *Isometroides vescus*. C, *Australobuthus xerolimniorum* sp. nov. Each pair shows the hemispermatophore with the lamina seen edge on, left, and rotated to the right by 90°, right.

form a right angle, whereas in the other two they form an obtuse angle open anteriorly.

Differences are also shown in the hemispermatophores (Fig. 13). These structures are strongly curved in three dimensions, and the appearance of the various features thus changes markedly with direction of view. The hemispermatophores of the three species are all of simple form with a curled flagellum, unlike that of *Isometrus melanodactylus* illustrated by Koch (1977) or the north African buthids illustrated by Vachon (1952). The degree of flagellar curling is simpler in the example of *Australobuthus* examined than in the other two. This may be a reliable character, but it is also possible that it reflects the state of maturity of the hemispermatophore. The proportions of the basal lobe and lamina do, however, distinguish the three distinctly.

Referred material: South Australian Museum: Sulphur Peninsula, Madigan Gulf, Lake Eyre North. 4.xi.1966. G.F. Cross. Mooring Station, Sulphur Peninsula, Lake Eyre North. 2.ix.1971. S end of Lake Gairdner. 13.x.1986. P. Hudson. Lake Gairdner. 25.xi.1959. B. Masou. Lake Gairdner. vii.1987. P. Hudson. (2 specimens) Lake Gairdner. 5.i.1989. P. Hudson. (3 specimens). Author's Collection: Lake Hart shore. xi.1984. B. Guerin. (2 specimens). Lake Hart shore. 27.i.1987. N.A. Locket. Lake Hart shore. 25-26.i.1988. N.A. Locket. Lake Hart shore. 5.i.1989. N.A. Locket.

Key to Australian Genera of the Subfamily Buthinae. (See Also Figs 5, 11, 13)

- 1 Tibial spur absent on third and fourth legs. *Isometrus*
Tibial spur present on third and fourth legs. 2
- 2 Vesicle with definite subaculear tooth or tubercle *Lychus*
Vesicle without definite subaculear tooth or tubercle 3
- 3 5th metasomal segment smooth, pitted, without keels.
Fourth and fifth metasomal segments and vesicle dark.
Vesicle and aculeus merge comma-shaped. Pectines with 20-28 teeth *Isometroides*
All metasomal segments keeled. Vesicle small but

distinct. Pectines with 30-36 teeth
..... *Australobuthus* gen. nov.

Discussion

Almost all the known specimens have been taken on the shores or surfaces of dry lakes, where they find cover by burrowing or by living beneath detritus. The burrowing habit appears to be unusual for a buthid species. The burrows, which the scorpion readily digs for itself in captivity, are very different from the spiral burrows of the scorpionid genus *Urodacus* (Koch 1978; Shorthouse & Marples 1980). In some cases the burrows in which *A. xerophilinorum* sp. nov. has been found may have been taken over from spiders or other burrowing animals: P. Hudson (pers. comm.) has recorded at least one from a lycosid burrow. Among Australian buthids, *Isometroides*, a specialised predator of burrowing spiders, has frequently been found in spider burrows, identified as such by the spider or remains of it being found in the burrow, or the presence of a trapdoor or silk lining. (Main 1956; Koch 1977). The latter mentions *L. alexandrinus* being found in spider burrows on occasion, but *L. marmoreus* and *L. variatus* are usually found under stones or bark.

Dedication

I dedicate this work to my father, George Hazelwood Locket, in his ninetieth year, and seventy-eighth as an arachnologist.

Acknowledgments

I wish to thank Dr Bernard Guerin for his gift of specimens amongst which I first recognised the new scorpion, Mr and Mrs Ian Read for their hospitality and for permission to look for scorpions on their property, Mr Peter Hudson for access to live specimens from Lake Gairdner, Dr David Lee for access to specimens in the South Australian Museum, Deirdre Locket for assistance in the field, Dr Gary Polis and Dr David Sissom for valuable discussions on problems of scorpion taxonomy and biology and Dr Sissom for access to his key to buthid genera. Mr G.R. Johnston gave valuable comments on the manuscript and Professor Robert Ussher gave advice on deriving the specific name.

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GEOGRAPHIC DISTRIBUTION OF THE FOSSORIAL HYLID FROG *CYCLORANA PLATYCEPHALA* (GÜNTHER) AND THE TAXONOMIC STATUS OF *C. SLEVINI* LOVERIDGE

BY MICHAEL J. TYLER

Summary

Published maps of the distribution of *Cyclorana platycephala* (Günther) differ markedly, and it has been evident that the latitudinal and longitudinal limits of the species require clarification. An investigation of all specimens in institutional collections in Australia demonstrates a continuous range from east to west, but with tenuous contact in central Australia. The distribution records are documented and attention is focussed upon an apparent isolate on the Stuart Highway at Dunmarra, N.T. The majority of specimens in collections are too poorly preserved for any meaningful analysis of morphometric divergence to be undertaken. Measurements obtained from small samples of the best-preserved specimens do not indicate any geographic trends. The types of *C. slevini* Loveridge have been examined and the opinion that this species is a junior synonym of *C. platycephala* is supported.

KEY WORDS: *Cyclorana platycephala*, *Cyclorana slevini*, distribution, taxonomy.

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TYLER, M. J. (1990) Geographic distribution of the fossorial hylid frog *Cyclorana platycephala* (Günther) and the taxonomic status of *C. slevini* Loveridge. *Trans. R. Soc. S. Aust.*, 114(2), 81-85. 31 May, 1990.

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Introduction

The accuracy of published distribution maps of species of Australian frogs reflects the effort of the compiler, the geographic detail available at the time, and the taxonomic expertise of identifiers. A broad-brush approach exaggerates and distorts the actual distribution. Given that published distribution maps are now being used by those assembling data relevant to conservation proposals, National Park proposals and other faunal documentation, accuracy is vital.

The existence of shared patterns of distribution amongst Australian frog species was first reported in a series of studies by Fletcher (1890, 1891, 1892, 1894, 1898), but analysis awaited the attention of Moore (1961), and most recently Tyler, Watson & Martin (1981) and Littlejohn (1981). Moore (1961) was a self-confessed taxonomic lumpen and so it is no surprise that he failed to recognise the existence of several cryptic species. Thus the peripheral, and supposedly continuous, northern and eastern coastal pattern that he named the 'northeast crescent' in reality was largely the combined distributions of groups of closely related species. For example the distribution attributed to *Litoria peronii* was that of *L. peronii*, *L. rothii* and *L. tyleri* combined, with *L. rothii* the sole species in the north and northeast of the crescent. Similarly, assumed patterns of allopatry between the southeast and southwest of the continent have been demonstrated to be based on distinct species (Littlejohn 1959).

As information improves, the overall trend is that fewer species are shown to have broad longitudinal distributions. An exception to that generalization is the fossorial hylid frog *Cyclorana platycephala* (Günther). But despite the fact that it is a well-known species because of its capacity to store large quantities of water prior to burrowing, and the ability of some aborigines to locate the frog to drink that water (Waite 1931), its geographic distribution is unclear.

Two recently published distribution maps (Fig. 1) differ in concepts of continuity and latitudinal and longitudinal limits (Cogger 1975; Tyler 1978), whilst Tyler, Davies & Martin (1983) reported a northward extension of the range of *C. platycephala*, through its occurrence on the Barkly Tableland of the Northern Territory.

Materials and Methods

To clarify the nature and extent of the distribution of *C. platycephala* I have examined specimens in all Australian natural history collections. The specimens examined are listed below. The acronyms used are as follows: A.M. (Australian Museum, Sydney); A.N.W.C. (Australian National Wildlife Collection, CSIRO, Canberra); C.A.S. (California Academy of Science, San Francisco); N.M.V. (Museum of Victoria, Melbourne); N.T.M. (Northern Territory Museum & Art Gallery, Darwin); Q.M. (Queensland Museum, Brisbane); S.A.M. (South Australian Museum, Adelaide); W.A.M. (Western Australian Museum, Perth). Letters preceding registration numbers are departmental identifications within the institutions.

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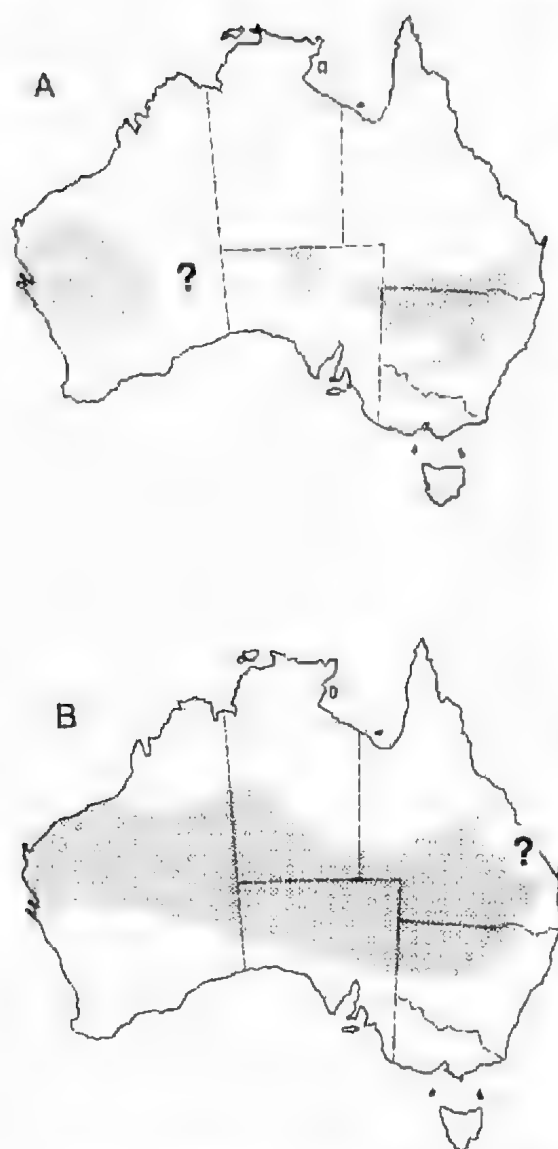


Fig. 1. Published maps of the geographic distribution of *Cyclorana platycephala*. A, from Tyler (1978); B, from Cogger (1975).

The bulk of the material is poorly preserved and distorted due to dehydration.

Western Australia: Milly Milly Stn, WAM R907-09; L. Monger, WAM R1146; Laverton, WAM R1441-94; Lander Stn, WAM R1635, 1659-71, 1890, 2682-88; Mt James Stn, N of Lander Stn, WAM R2693-95; Gwalia, WAM R7774-80; 2 km N of jcn of Gascoyne R. and Aurillia Ck, WAM R1635; between Karagullen & Pickering Brook, WAM R34784; Prairie Downs Stn, WAM R19187-90; 3 km SW of Wilgie Mia, WAM R19160-65; Malcolm Dam, 10 km E of Leonora, WAM R50044; 20 km N of Leonora-Laverton Rd junction, WAM R28973-81; 12 km E of Laverton, WAM R48990; Uroborunda Ck, Millbailie Stn,

ANWC A1145, 1150-51, 1185-87; North Pool, Willuna, ANWC A1153; Warriedar, WAM R1406-16; Well 26, Canning Stock Route, WAM R4079; Windich Spring, Canning Stock Route, WAM R4135, SAM R51712-16; Mileura, WAM R13978; 15 km S of Meekatharra, WAM R20547-49; Warburton Mission, WAM R21320; Jigalong, WAM R28550-54; 33 km S of New Mundiwindi, WAM R28972; 54 km S of Leonora, WAM R29880-81; nr Mt Tom Price Minesite, WAM R31026; S of Wining, WAM R33208; 16 km S of Minilya River, WAM R33209; Morawa, WAM R33306-14; Barrow Island, WAM R40026, 45736-38, 52640-50; 19 km ESE of Wydgie Hstd, WAM R49280; Durba Springs, WAM R51945; Meekatharra, WAM R54386; 4 km S of Mt Narryer Hstd; 33 km NNE: Kumarina, WAM R63103-05; 15 km E Nullagine, WAM R63113; Condegoon Pool, WAM R63834-35; 21 km SSE of Mt Keith, WAM R64969; 22 km SE of Mt Keith, WAM R64970; 11.5 km N of Erlistoun, WAM R64971-72.

Northern Territory: No. 26 Borc, Alloy Downs, NTM R9711-16; Charlotte Waters, NMV D3263, 5703, 5708, 5723-26, 5728-32, SAM R16921A-D, R19191; Dunmarra, AM R60331-36, NTM R8609; 8 km S of Dunmarra, NTM 9598-604, 9674; Etahakinna Ck, NTM 5925; Palm Valley, WAM R21535, 96360-68.

South Australia: Oodnadatta, NMV D12694-97; Kue Dam, 8 km E of Farina, SAM R8930; Etadunna Stn, SAM 14185; Box Hole Ck, 77 km NW of Coober Pedy, SAM 13279; 60 km NNE of Oodnadatta, SAM 16314, 26939-40; Coongie Lakes, SAM R30992-93, R32421-45, 33381-82; Gidgealpa W.H., SAM R27358.

Queensland: Rocklands Stn, NTM 13177-79; Wilkie Ck, 24 km SW of Dalby, QM J12358, 12367, 12369; Dalby, QM J17393-94; Warrabee, QM J17395; Waratah Stn, Cunnamulla, QM J17396, 17398; Goondiwindi, QM J17397; 0.5 km W of Windorah, QM J28590-93; West Wyalong, QM J39247-48; Cuddapanna Hstd, W of Windorah, QM J28541-42; Mornay Stn, Windorah, QM J28543; Adria Downs, 55 km NW of Birdsville, AM R113230; 5 km E of Enlo, AM R79416-18; St George, AM R89775-78, SAM R3719; Cunnamulla, AM R18365, 20490-91; Farrars Creek Crossing QM J44074; near Dirrinbandi, QM J46585-88; Durham Downs, 260 km W of Thargomindah, QM J46589; Dynevor Downs, 60 km E of Thargomindah, QM J46591, 46593-95, 46612, 46617-18; Nanyileo Stn; Warri Ck, QM J46596-6611, 46613-15; Nappa Merrie Stn, QM J46616, 46619-23; Bullawarra Stn, 40 km W of Thargomindah, QM J46592; Noondoo, AM R 13816 (*C. slevini* paratype), CAS 82052 (*C. slevini* holotype).

New South Wales: Halls Ck, Willandra N.R., Hillston, AM R54896-97; Yancannia Stn, NMV D10698-99, SAM R5473A, 5473B; 2 km E of Thurloo Downs Hstd, AM R102887; 20 km W of Byrock, AM R58163-72; The Plains, Nyngan, AM R11782, 11789, 58173; Booligal AM R71912-22; 2 km E of Thurloo Downs Hstd, AM R102887; Namoi R., Narrabri, AM R4638; Goangra nr Wilgett, AM R7343; Maxland, Mungindi, AM R14918; 20 km W of Byrock, AM R15239; Brewarrina, AM R15771, 15775, 16088-93; 10 km W of Byrock, AM R18338-53; Quainbone, AM R18710; Merri Merri Ck, nr Carinda, AM R28196; Stuart N.P., Tibooburra, SAM R14080, AM R42142-12; 16-32 km S of Condobolin on West Wyalong Rd, AM R51221-31; Nocolche Nature Res.,

ANWC A1633; 40 km S of Walgett, ANWC A1266; Sandy Camp, Macquarie Marshes, ANWC A1326; Boolka L., via Torrowangie via Broken Hill, SAM R2063; 80 km N of Broken Hill, SAM R12534-40; 22 km E of Hay, SAM R13501A-B; 16 km W of Hay, SAM R13502, 50 km E of Hay, SAM R13503; Fowlers Gap Stn, 110 km N of Broken Hill, SAM R24350-51.

Methods of measurements and abbreviations used in Table 1 follow Tyler (1968).

Results

The distribution map prepared from the preceding records is presented as Fig. 2. It reveals that, contrary to the suggestion of Tyler (1978), there is probably no geographic discontinuity between the southwestern and the southeastern populations, but that the area of contact is tenuous. In addition it shows that the longitudinal and latitudinal assumptions of Cogger (1975) are exaggerated (Fig. 1). Morphometric data of various samples are presented in Table 1.

The western component of the species extends from the Hammersley Ranges south and east to the Great Victorian Desert. The eastern component clearly is associated with the Lake Eyre Basin and with the Darling and Murrumbidgee drainage systems, except for extreme southeast Queensland where the species extends to the east of the Great Dividing Range.

Three N.T. records extend far beyond the overall range: No. 26 Bore at Alroy Downs on the Barkly Tablelands, Dunmarra and 8 km S of Dunmarra on the Stuart Highway (Fig. 1). The drainage of Alroy Downs is linked to the Ranken River to the west, a tributary of the Georgina River which flows into the Lake Eyre Basin. There has been very little collecting along the Georgina River (access is difficult, particularly in the wet season) and it is quite possible that *C. platycephala* occurs along its length.

Cyclorana slevini Loveridge (1950) was described from two specimens from Noondoo (Fig. 2) in

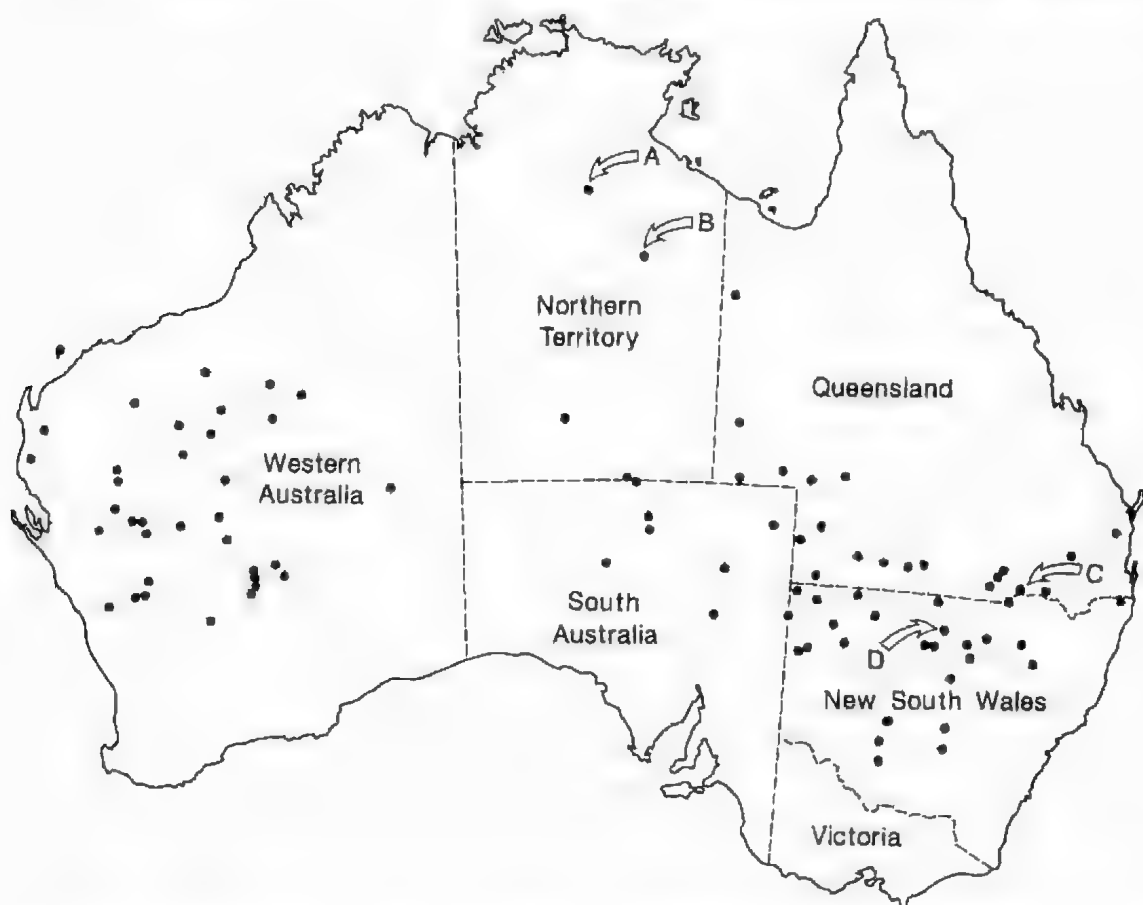


Fig. 2. Geographic distribution of *Cyclorana platycephala* based on specimens in Australian museums. A = No. 26 Bore, Alroy Downs; B = Dunmarra; C = Noondoo (type locality of *C. slevini*); D = Fort Bourke (type locality of *C. platycephala*).

southeast Queensland. A photograph of the preserved holotype, a diagnosis and notes on the collection of the specimens were provided by Slevin (1955). In his paper Loveridge stated that, in accordance with Australian law, the holotypes of this and two other species were being presented to the Australian Museum. A footnote, evidently added in galley proof, indicated that, whereas the holotypes of two other species had been transferred, the paratype of *C. slevini* had been substituted for the holotype. Why this action was taken is unclear.

Moore (1961), presumably with access to the paratype, considered *C. slevini* a valid species, and included it in a series of species known only from southeast Queensland, but which he considered would also be found in northeast New South Wales.

Dr H.G. Cogger showed me the paratype in 1968, and I agreed with his opinion that it was a junior synonym of *C. platycephala*. Hence I omitted *C. slevini* from a list of the frog fauna of Queensland (Tyler 1975).

Cogger, Cameron & Cogger (1983) listed *C. slevini* as a junior synonym of *C. platycephala*, but the action was not supported by Frost (1985) because it had not been substantiated by data. Accordingly I have re-examined both types to provide data and to formalise the suppression of *C. slevini* because that action appears to be required.

The types of *C. slevini* are dehydrated, sub-adult specimens. In both specimens the broad, flattened head, small eyes, extensively webbed toes and grey coloration are features characteristic of *C. platycephala*.

The type locality of *C. slevini* is close to the type locality of *C. platycephala* (Fort Bourke, N.S.W.). I have no hesitation in confirming that *C. slevini* should be referred to the synonymy of *C. platycephala*.

Discussion

The data indicate that *C. platycephala* does indeed have an extensive geographic distribution, involving a pattern that is unlike that of any other Australian anuran. Historically one significant

factor is that the process of speciation in southern Australia has been a consequence of the separation of former transcontinental distributions into eastern and western isolates. The distribution of *C. platycephala* presented by Tyler (1978) questioned whether geographic separation had occurred. It would seem that that is not the case, but that continuity is maintained.

Several interpretations of the distribution pattern could be postulated, and I suggest that an understanding of the history of the species in the northern portion of the N.T. is particularly relevant in that regard.

The records at and near Dunmarra appear to be geographically isolated. With my colleagues M. Davies, G. F. Watson, A. A. Martin and D. J. Williams I have visited these sites on several occasions without locating the species; but our visits have not coincided with favourable wet conditions. We have noted that the area from Dunmarra to about 15 km south is a plain of cracking clays isolated from the adjacent area and from similar soils on Alroy Downs and other sites on the Barkly Tableland to the east where the species occurs. That area is virtually unexplored zoologically but our observations at its periphery indicate that *C. platycephala* does not occur there. Thus the distribution of the species may have been more extensive in the past. Further biochemical and biological data are required to determine whether significant intraspecific divergence can be detected within the current geographic range.

Acknowledgments

For information upon and the loan of specimens I thank H.G. Cogger, J. Coventry, A. Edwards, P. Horner, G.J. Ingram, A. Leviton, M. King, K.R. McDonald, R.A. Sadler, L.A. Smith, G.M. Storr and J. Wombey.

The investigation was supported by the University of Adelaide. I thank Veronica Waid for technical assistance and for preparing the figures, and Lorna Lucas for typing the manuscript.

TABLE 1: Dimensions and proportions of selected samples of adult *Cyclorana platycephala*.

Locality	n	SV	SV	SV	HL/HW	HL/SV	E-N/IN
Dunmarra, N.T.	8	52-57	54-68	.31-.39	.78-.84	.32-.38	.97-1.11
Alroy Downs, N.T.	6	54-56	60-66	.34-.39	.77-.80	.34-.37	.95-1.12
Charlotte Waters, N.T.	8	55-64	65-68	.33-.40	—	—	—
nr Condobolin, N.S.W.	11	42-56	52	.35-.40	.74-.83	.33-.37	1.10-1.29
Boolligal, N.S.W.	10	51-55	50-60	.33-.38	.73-.82	.32-.37	1.10-1.29
Prairie Downs Stn, W.A.	2	—	55-60	.35-.40	.82-.88	.32-.34	1.21-1.37
Leonora area, W.A.	6	50-54	57-65	.35-.39	.80-.88	.32-.38	1.10-1.29
Wilkie Ck, Qld	3	39-49	—	.34-.40	.77-.80	.35-.41	1.06-1.13
Windorah, Qld	7	54-63	61-72	.33-.37	.76-.81	.32-.35	1.07-1.31
Dynevor Downs Stn, Qld	5	47-54	68	.34-.40	.79-.84	.32-.37	1.19-1.38
Nappa Merrie Stn, Qld	5	41-57	—	.39-.42	.81-.85	.37-.39	1.14-1.28

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**THE NEW GUINEA GENUS COPIULA MÉHELÿ
(ANURA: MICROHYLIDAE): A NEW DIAGNOSTIC CHARACTER AND
A NEW SPECIES**

BY THOMAS C. BURTON

Summary

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KEY WORDS: frog, microhylid, *Copiula*, pectoral muscles, deltoid, new species, morphology.

THE NEW GUINEA GENUS *COPIULA* MÉHELÿ (ANURA: MICROHYLIDAE): A NEW DIAGNOSTIC CHARACTER AND A NEW SPECIES

by THOMAS C. BURTON*

Summary

BURTON, T. C. (1990) The New Guinea genus *Copiula* Méhely (Anura: Microhylidae): a new diagnostic character and a new species. *Trans. R. Soc. S. Aust.* 114(2), 87-93, 31 May, 1990.

Copiula Méhely possesses a unique condition of the deltoid musculature. The nature of the throat musculature of *Copiula* suggests a phylogenetic affinity to *Sphenophryne*. *Copiula tyleri* sp. nov. a widespread species, occurring in the north of the New Guinea mainland, is characterized by an unpigmented tympanum, strong contrast between the mid-dorsal and latero-dorsal ground colour, a broad, short truncate snout, and nostrils that open laterally rather than anterolaterally. There remains a number of specimens of *Copiula* that cannot be associated confidently with any of the named species.

KEY WORDS: frog, microhylid, *Copiula*, pectoral muscles, deltoid, new species, morphology.

Introduction

Copiula Méhely (1901) was erected to accommodate *Phrynxalus oxyrhinus* Boulenger (1898). Parker (1934) referred *Copiula* to the synonymy of *Cophixalus*, where it remained until Menzies & Tyler (1977), with access to newly available specimens, resurrected it for *C. oxyrhina* and two new species, *C. fistulans* and *C. minor*. Burton & Stocks (1986) described a fourth species (*C. pipiens*) from specimens collected in 1983. In their account of the systematics of *Copiula*, Menzies & Tyler (1977) emphasized three features that distinguish it from *Cophixalus* Boettger, the other genyophrynine genus then consisting of frogs lacking clavicles and procoracoids: (a) rostral glands and an associated translucent white tip to the snout; (b) premaxillae with broad-based alary processes; and (c) finger discs less expanded than toe discs.

There are problems with the above diagnosis. R. G. Zweifel (*in litt.*) points out that *Cophixalus paucus* and *C. sphagnteola* lack expanded finger discs so that the toe discs are broader at their tips than the fingers (Zweifel & Allison 1982). Moreover, Zweifel points out that some species of *Sphenophryne* (among them *S. schlaginhaufeni* (pers. obs.)) possess translucent, glandular tips to their snouts. Finally, I have been unable to confirm the difference in the morphology of the premaxillae: the alary processes of specimens of *Cophixalus riparius* and *C. ornatus* examined in this study are broad-based and appear similar in structure to those of *Copiula fistulans*. Paradoxically, species of *Copiula* are probably easier to assign to genus than any other genyophrynine species, but neither external morphology nor skeletal structures yield unequivocal characters to support the genus.

It is clear, however, that characters of the musculature are useful at all levels, including generic, in the systematics of microhylid frogs. Burton (1986) based much of his revision of the Asterophryinae on characters of the musculature. In the present study, muscles of the throat, pectoral girdle and foot provide useful information and are introduced here.

Frogs possess three transversely directed muscles between the mandibles: the *M. submentalis* (the most anterior), the *M. intermandibularis* and the *M. interhyoideus*. In addition, the microhylids possess one or more supplementary slips to the *M. intermandibularis* (Tyler, 1974¹; Emerson 1976). All of the genyophrynines possess one supplementary slip (Burton 1986), but exhibit diversity in its origin and orientation. This diversity has proven taxonomically useful at various levels (Tyler 1974¹; Burton 1984, 1986).

Burton (1983a²) showed that the condition shared by some members of all of the microhylid subfamilies that he examined was a single narrow supplementary slip arising via a tendon from posteriorly on the mandible and passing anteromedially, parallel with the mandible, to insert on a median tendinous mass underlying the junction of the mentomeckelians. This condition is figured for *Cophixalus ornatus* by Burton (1984) and *C. kainiensis* (Burton 1986). Its distribution through several subfamilies (Asterophryinae, Brevicipitinae, Dyscophinae, Genyophryninae and Microhylinae) suggests that it is the primitive condition, using the criterion of Kluge (1976) that a character state widespread among taxa related at

Tyler, M. J. (1974) Superficial mandibular musculature and vocal sac structure of the Anura. M.Sc. thesis, University of Adelaide. Unpubl.

² Burton, T. C. (1983a) The phylogeny of the Papuan subfamily Asterophryinae (Anura: Microhylidae). Ph.D. thesis, University of Adelaide. Unpubl.

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the next higher taxonomic level that otherwise have little in common is plesiomorphic.

The deltoid muscle of frogs usually consists of two or three slips inserting on the humerus, the number of slips depending in part on the completeness of the pectoral girdle (Jones 1933). The *M. episternohumeralis*, arising from medially on the ventral surface of the sternum and/or episternum (depending on the presence of an episternum), and the *M. acromiohumeralis*, arising from the scapula, are apparently always present, however much the pectoral girdle may be reduced (Jones 1933; Burton 1983a²). Frogs with a "complete" pectoral girdle, i.e., including a fully developed clavicle, usually possess a small slip, the *M. cleidohumeralis*, arising from the ventral surface of the clavicle. No genyophryine, even if it possesses a clavicle, possesses this slip (Burton 1983a²).

The *M. acromiohumeralis* is generally (e.g., *Rana temporaria*, Ecker 1889; personal observations) a broad muscle consisting of (a) short fibres from the anterior margin of the scapula which insert along the ventral surface of the humerus, and (b) a long superficial strap-like portion which consists of parallel sets of fibres arising from two origins. The more medial fibres arise from laterally on the anterior margin of the acromion; the more lateral fibres arise from the medial surface of the scapula, pass laterally, curving around the dorsal surface of the acromion, and run alongside the more lateral fibres from the anterior margin of the acromion. This strap-like component of the deltoid musculature runs the length of the humerus, and inserts on the ulnar epicondyle of the humerus. In genyophryines of the genera *Cophixalus* and *Sphenophryne* examined in this study, these fibres arise distally on the posterior surface of the coracoid instead of the medial margin of the scapula.

Burton (1983a²) demonstrated that the foot and hand musculature of the New Guinea microhylids is very conservative and, therefore, useful taxonomically. In genyophryines a foot muscle, the *M. flexor ossis digiti IV*, typically arises from the fibulare and inserts along the whole length of the lateroplantar surface of metatarsus IV.

When Menzies & Tyler (1977) resurrected *Copiula* they dealt only with species from eastern New Guinea, while acknowledging the existence of specimens from the Cyclops Range in Irian Jaya, 800 km west of their most westerly site for *C. fistulans*. *Copiula pipiens* was subsequently described from Wewak, 500 km north-west of the species discussed by Menzies & Tyler (Burton & Stocks 1986). In the course of a broader study of *Copiula*, a series of morphologically distinctive

frogs was found to have been collected from a number of sites ranging from the Cyclops Range eastwards to within about 200 km north-west of the known range of *C. fistulans*.

Materials and Methods

The following specimens were examined for comparison with the new species, and are lodged in collections abbreviated as follows: AMNH - American Museum of Natural History, New York; AUZ - Department of Zoology, University of Adelaide (unregistered); BMNH - British Museum (Natural History, London); RMNH - Rijksmuseum van Natuurlijke Historie, Leiden; SAM - South Australian Museum, Adelaide; UPNG - Department of Biology, University of Papua New Guinea, Port Moresby.

Copiula fistulans Menzies & Tyler AMNH 59894-6, 81128-31, 82951-2; AUZ A723, D742; SAM R5852, R5879, R6282-3, R9443-8, R14239-50, R14497 (holotype), R18081, R23836-7; *C. minor* Menzies & Tyler AMNH 56908, 56939-40, 56958, 56960, 56971-2, 56986, 56997-8, 57046-7, 57050-4; SAM R15245 (paratype); *C. oxyrhina* (Boulenger) AMNH 59894-8, 59957-60, 59992-60000, 60013, 60018-9, 60036-46; BMNH 1947.2.11.99, 1947.2.12.4 (syntypes); SAM R 10647, R 14237-8, R18080; UPNG 1371, 2612, 4311, 5204-5; *C. pipiens* Burton & Stocks type series AMNH 123698; SAM R 29779 (holotype)-82; UPNG 7025-8 (incorrectly cited by Burton & Stocks (1986) as 7205-8); unidentified *Copiula*: AMNH 49536, 49554, 79961; BMNH 1935.6.6.2.3; RMNH 5256, 5269.

Other Genyophryinae: *Cophixalus ornatus* SAM R12321; *C. parkeri* SAM R5578A, R5818A, R5823A; *C. riparius* SAM R6145, R9125A; *Sphenophryne macrorhyncha* SAM R6395; *S. palmipes* SAM R1157.

Other Microhylidae: *Hylophorbus rufescens* SAM R6285B; *Katoula picta* SAM R13603B; *Mantophryne lateralis* SAM R5881A, R9434A; *Phrynomantis hunicola compta* SAM R5825A; *P. stictogaster* SAM R5202.

Other families: Hylidae: *Litoria caerulea* SAM R23974; Leptodactylidae: *Limnodynastes peroni* SAM R24273; *L. dumerili* SAM R19100; Ranidae: *Rana grisea* SAM R8294B; *R. papua* SAM R7695.

Specimens were preserved in 65% or 70% ethanol. The following measurements were taken: Snout-vent length (S-V), head width (HW), head length (HL), tibial length (TL), Eye diameter (E), Eye-naris distance (E-N), internarial distance (IN), diameter of tympanum (T), and snout length (SN). Measurements were carried out using Mitutoyo dial calipers, and follow the methods of Burton & Stocks (1986). Myological dissections were facili-

tated by use of the iodine-potassium iodide solution of Bock & Shear (1972).

Specimens were, or had been, cleared and double-stained for skeletal examination according to the method of Dingerkus & Uhler (1977). Some specimens were flensed and cleared of soft tissue by application of sodium hypochlorite solution and allowed to dry slowly. Nomenclature of muscles and skeletal structures follows Burton (1986).

Myological Characters of *Copidula*

The superficial throat musculature of *Copidula* includes a single supplementary slip of the *M. intermandibularis*; a broad sheet arising from the anterior part of the ventral margin of the angulosplenial, and passing medially and only slightly anteriorly to insert on the ventral epimysium of the *M. submentalis* and the adjacent median aponeurosis of the anterior portion of the *M. intermandibularis*. This slip was illustrated by Burton (1986), and resembles closely that of *Sphenophryne* described and figured by Burton (1984).

The lack of clavicles and procoracoids led Parker (1934) to associate *Copidula* with *Cophixalus* but the nature of the throat musculature is stronger evidence of the phylogenetic relationships of *Copidula* with *Sphenophryne*, as it is clearly a synapomorphy (Burton 1986). It is likely that clavicles and procoracoids have been lost several times in the evolution of the New Guinea microhylids (Burton 1986) and that reduction of the pectoral girdle, therefore, is not a reliable phylogenetic character.

The deltoid musculature of *Copidula* (Fig. 1) resembles that of other genyophrynines, except that the portion of the *M. acromiohumeralis* which arises from the coracoid of *Copidula* differs from that of other genyophrynines in origin, course and insertion. In *Copidula* this portion has a broad origin occupying the middle one-half approximately of the anterior margin of the coracoid. The fibres of this portion converge as they pass anterolaterally across the anterior margin of the acromion (dorsal to the lateral surface of the humerus. Instead of merging with the strap-like portion from the acromion, as in other frogs, it passes medially, deep to the strap-like portion, and inserts on the crista ventralis and the adjacent lateroventral surface of the humerus. This condition is not found in other New Guinea microhylid genera, or in the other 22 microhylid genera examined by Burton (1986), and has not been reported for any other genus.

This unique muscle slip is found easily in dissection of the pectoral girdle, and in some spirit

specimens with translucent ventral skin it can be seen clearly through a dissecting microscope sometimes without making an incision. In that the condition described here is found in all frogs referred to *Copidula* by the combination of characters presented by Menzies & Tyler (1977), and in that this slip is unique to *Copidula* and is relatively easy to find, possession of this condition of the deltoid musculature is diagnostic for *Copidula* and taxonomically useful.

The *M. flexor ossi digiti IV* of *Copidula* inserts only on the proximal one-half of the lateroplantar surface of metatarsus IV. This is the condition shared by most of the asterophryine genera but no other genyophrynine, and is described and figured by Burton (1983 b). As it is a difficult muscle to

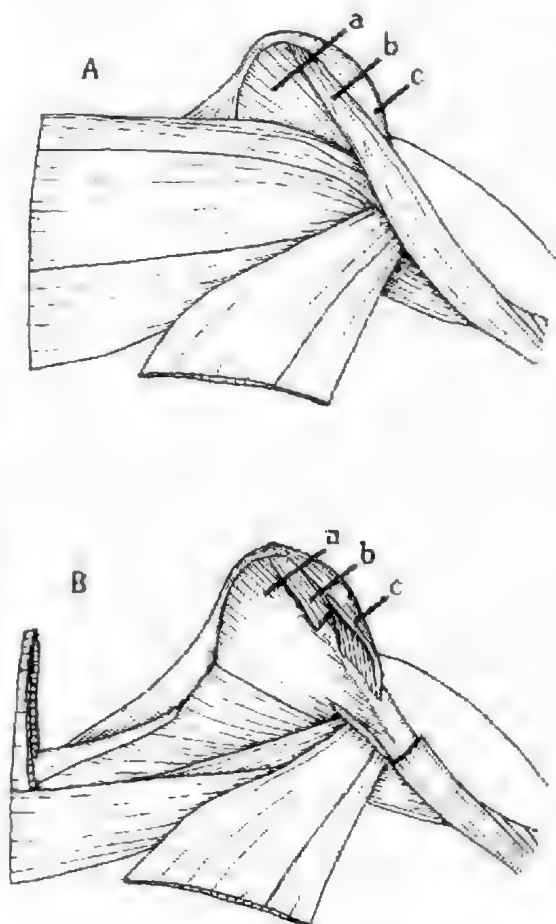


Fig. 1. Ventral views of the pectoral musculature of the left side of *Copidula tyleri*, sp. nov., showing the components of the *M. acromiohumeralis* A, with all muscles intact, and B, after removal of superficial muscles and severing of strap-like portion from acromion; a, short fibres from coracoid; b, strap-like portion; c, portion originating from coracoid.

dissect, it is of use in phylogenetic studies rather than of taxonomic value.

Copiula tyleri sp. nov.

FIGS 2-5

Holotype: AMNH 77542, an adult male collected at Mt Hunstein, 1220 m, 142°39'E, 4°31'S, East Sepik Province, Papua New Guinea on 15.viii.1966 by R. Hoogland.

Definition: A small species with a conspicuously unpigmented tympanum; dorsum distinctly more heavily pigmented medially than laterally; snout relatively short ($SN/E < 1.40$) and broad; the nostrils opening laterally.

Description of holotype: Head roughly triangular, longer than broad (HL/HW 1.06) (Fig. 2). Head width more than $\frac{1}{2}$ snout to vent length ($HW/S-V$ 0.36). Snout relatively short (SN/E 1.31), with rounded, translucent white tip projecting well beyond maxillae. Nostrils lateral; internarial distance much greater than eye to naris distance ($E-N/IN$ 0.61). Canthus rostralis well defined and curved when seen from above; loreal region almost vertical. Eye small ($E/S-V$ 0.106), but larger than eye-to-naris distance. Tympanum small (1.6 mm) and conspicuously unpigmented in contrast to dark pigment of side of head and scapula area; no supratympanic fold.

Tongue more than half free posteriorly. Single transverse prepharyngeal ridge present, denticulate.

Fingers and toes unwebbed (Fig. 3); terminal discs with marginal grooves; discs of toes broader than discs of fingers; order of lengths of fingers $3 > 4 > 2 > 1$; order of lengths of toes $4 > 3 > 5 > 2 > 1$; inner metatarsal tubercle small and oval; outer metatarsal tubercle absent.

Skin of dorsal and ventral surfaces smooth. Colour in preservative: dorsum mid purplish-brown medially, with indistinct dark brown to black blotches, grading laterally to a pale grey contrasting strongly with dark postorbital strips. Tip of snout unpigmented. Postorbital stripe broad and irregular, extending beyond arm. Flanks dark brown blotched pale grey. Tympanum golden-brown contrasting with dark postorbital stripe. Ventral surfaces pale.

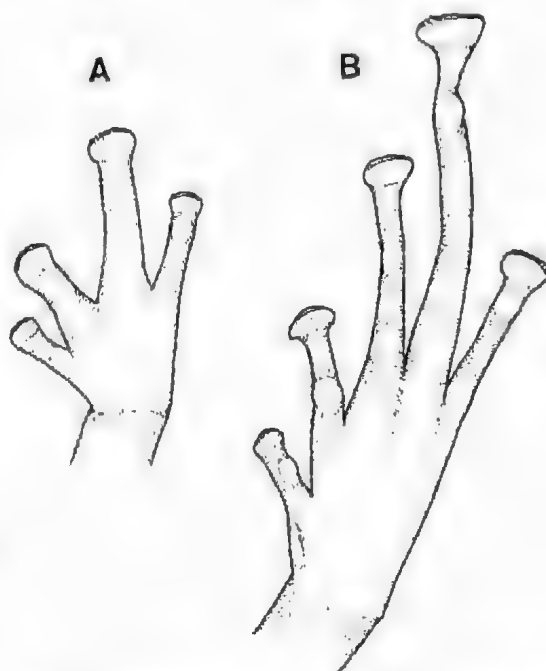


Fig 3. A, palmar surface on the left hand and B, plantar surface of the left foot of the holotype of *Copiula tyleri* sp. nov.

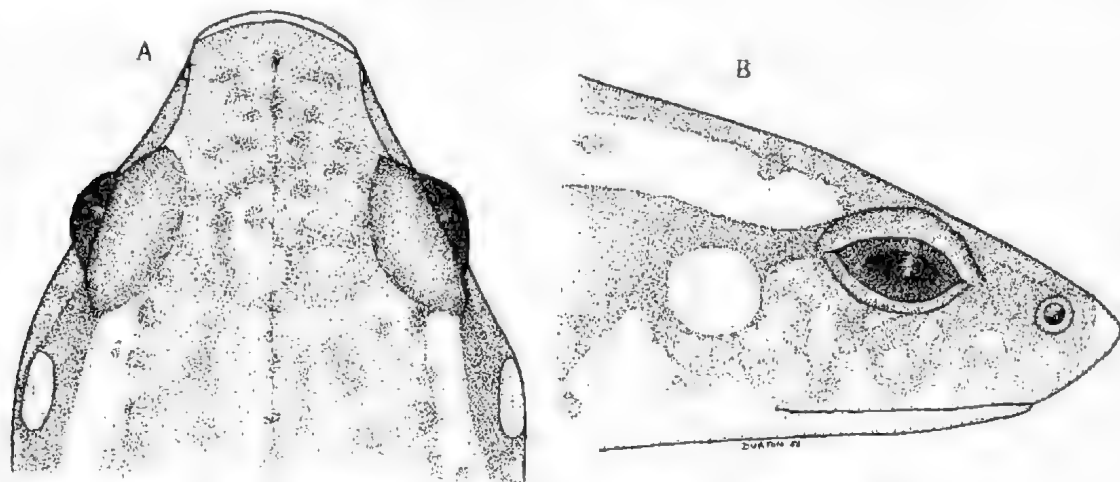


Fig. 2. A, dorsal and B, lateral views of the head of the holotype of *Copiula tyleri* sp. nov.

NEW *COPILA* SPECIES

cream-grey, suffused with brown in submandibular region and on undersurface of tibia and foot.

Iliosacral articulation direct and ligamentous.

There is no information on the call of this species.

Dimensions of holotype: S-V 24.5 mm; HW 8.7 mm; HL 9.2 mm; TL 12.1 mm; E 2.6 mm; E-N 1.7 mm; IN 2.8 mm; T 1.6 mm; SN 3.4 mm.

Etymology: The species is named in honour of Michael J. Tyler, whose contribution to the taxonomy of Australian and New Guinean frogs is immense, who, with Menzies, resurrected *Copila*, and to whom the author is deeply indebted personally and professionally. It is evidence of the perversity of nature that the legs of *Copila tyleri* are as moderate in length as Tyler's aren't.

Variation

There are 13 paratypes: AMNH 78113 (gravid ♀), Mt Nebo, 700-1550 m, 20 km NE of Lumi, 142°2'E, 3°25'S, West Sepik Province, J. Diamond 14.vii.1966; AMNH 78114 (gravid ♀), Mt Menawa, Bewani Mtns, 15 km NE of Utai, 141°33'E, 3°22'S West Sepik Province, J. Diamond 2-8.viii.1966; AMNH 77543 (gravid ♀) collected with the holotype; AMNH 82949 (adult ♂), Wanuma, 145°20'E, 4°50'S, 670 m Adelbert Mtns, Madang Province, R. G. Zweifel 3.viii.1969; BMNH 1938.6.5.93-96,98 (adult ♂♂), 1938.6.5.97, 99 (immature ♀♀), Cyclops Range, 910-1220 m, Irian Jaya ca 140°40'E, 2°30'S, E. Cheesman; SAM R33774 (adult ♂) collected with the holotype. More precise data of sites and dates of capture are unavailable for the Cyclops Range specimens.

The adult males measure 19.6-24.5 S-V, and the females 24.2-25.5 mm S-V. The diameter of the largest unpigmented mature ovum observed is 2.9 mm. Hind limbs are moderately long (TL/S-V 0.45-0.49). HL/HW varies widely (0.93-1.13). SN/E is very low (1.20-1.31). E-N/IN varies between 0.60-0.79.

Coloration in preservative varies. In general specimens from the Cyclops Range are browner, sometimes honey-coloured, whereas specimens from elsewhere are grey-purple. Whether this reflects different length of preservation (the Cyclops Range specimens were collected approximately 30 years before the others), or the preservative practices adopted by collectors or museums, or any real difference is unclear. The postorbital stripe varies in breadth and extent, but it is broad and extends beyond the arm in all specimens.

Ventral colour ranges from pale mauve through pale cream, and in some specimens the ventral colour of the thigh is pale orange. Density of the mottling of the submandibular region varies from slight peppering to heavy mottling.

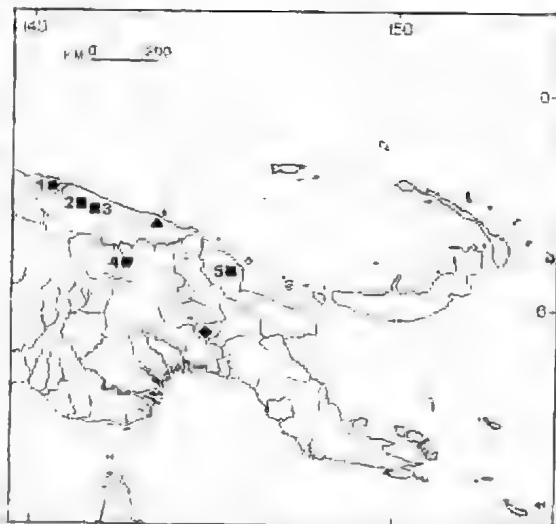


Fig. 4. Distribution of *Copila tyleri* sp. nov. in Eastern New Guinea, *C. pipiens* and an unidentified *Copila*. *C. tyleri*: squares, 1, Cyclops Ra; 2, Mt Bewani; 3, Mt Nebo; 4, Mt Hunstein; 5, Wanuma. *C. pipiens*: triangle Wewak district. Unidentified *Copila*: diamond Soliabeda.

Habitat and Distribution

In his field notes on AMNH 82949, R. G. Zweifel states, "I found this one hiding beneath a broad leaf on the forest floor in the daytime. When uncovered, it tried to hide in a hole in the ground". The Cyclops Range specimens were collected from "dense forest".

Information regarding the altitudes of collecting sites is sketchy, but the minimum range of altitudes is 670 m (Wanuma) to 1220 m (Mt Hunstein and Cyclops Ra). Collecting sites are marked on Fig. 4. All sites are to the north of the central highlands.

Colour in Life

R. G. Zweifel has supplied field notes of one of the paratypes (AMNH 82949): "Mid-dorsal area from snout to cloaca moderately dark brown edged laterally with lighter, more golden brown. There is a dark lateral band from the snout to mid-flank that is much darker brown than the middle of the back. A light yellow line separates this dark brown from the lighter brown of the snout along the canthus rostralis, and this line continues up over the edge of the eyelid. The upper surfaces of the limbs are much the same colour as the middle of the back but have a few lighter and darker speckles on them. The under surfaces are grayish white with a faint yellowish tinge in the groin and in the axillary regions. There is a general grey mottling on the chin which is much weaker on the chest and entirely absent on the lower abdomen. Similar mottling

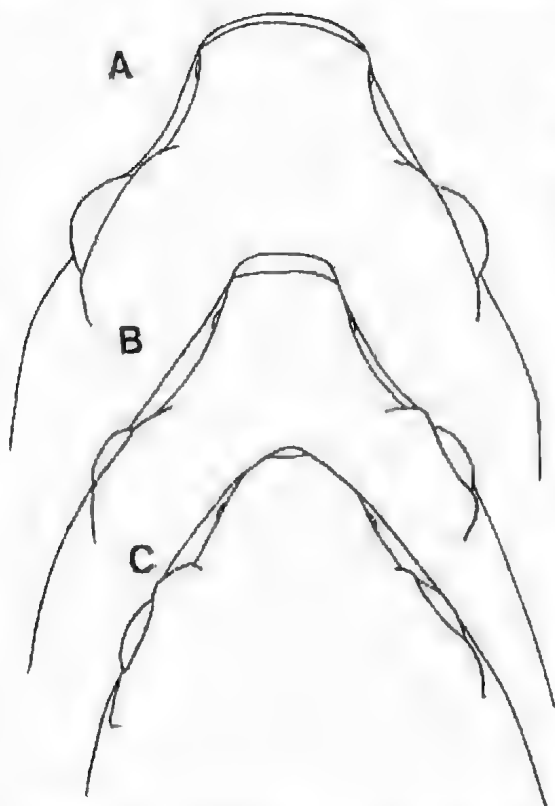


Fig. 5. Outlines of dorsal views of heads of A, *Copiula tyleri* sp. nov.; B, *C. pipiens* Burton & Stocks; C, *C. minor* Menzies & Tyler.

reappears on the under surfaces of the hind limbs. The iris is dark brown, almost black, with tiny golden flecks. The horizontal pupil is conspicuously margined with a reddish gold line".

Comparison with other species

Copiula tyleri sp. nov. is a small species (maximum size of adult males 24.5 mm, females 25.5 mm S-V), distinct on this account from *C. fistulans* adult males (25.1-29.2 mm, females 29.4-33.5 S-V). Unlike the other small species (*C. minor*, *C. oxyrhina*, *C. pipiens*) there is strong contrast between the dark mid-dorsum and paler lateral dorsum, the tympanum is generally conspicuously unpigmented (Fig. 2) (dark and indistinct in other species), and the snout is truncate and broad, the nostrils opening laterally (Fig. 2) (anterolateral opening in other species). Fig. 5 shows a comparison between the shapes of the snouts of *C. tyleri* sp. nov., *C. minor* and *C. pipiens*. *C. oxyrhina* is so variable as to preclude its representation by a single morphotypy (Burton & Stocks, 1986).

Copiula tyleri sp. nov. differs from *C. fistulans*, *C. minor* and *C. oxyrhina* in having a direct ligamentous attachment between the ilium and sacrum. *C. pipiens* shares the *C. tyleri* condition, but can be distinguished by characters of the dorsum, tympanum and snout noted above, and probably by colour in life, as *C. pipiens* is tinged orange-pink in areas of the back and vent, compared with Zweifel's account of *C. tyleri* above. The snout of *C. pipiens* is relatively long (min. SN/E 1.45 compared with *C. tyleri* max. SN/E 1.31) (Fig. 5).

The shared possession of a direct ligamentous attachment between the ilium and sacrum may suggest that the closest relation of *C. tyleri* sp. nov. is *C. pipiens*, but the polarity and hence utility of this character is unknown (Burton 1986). The range of *C. pipiens* is poorly known: the only specimens were obtained from the Wewak area (Fig. 4). The range of *C. tyleri* apparently surrounds that of *C. pipiens*, but there is no information to suggest that the ranges of the two species abut or overlap.

Unidentified mainland specimens

Two specimens from Mt Nomò, Irian Jaya (BM NH 1938.6.6.2-3) probably represent a further undescribed species. Both are small (S-V 19.1, 18.3), slender and little pigmented, and BMNH 1938.6.6.2 possesses a very long snout. Unfortunately, these specimens are in poor condition because of previous exploratory dissection and it is impossible to sex or age them, or to determine the relationship between the ilium and sacrum.

AMNH 49536 and 49554 (juvenile) from Bernhard Camp, Idenburg River, Irian Jaya cannot be referred to the species closest geographically, *C. pipiens* and *C. tyleri*, as they lack the direct ligamentous attachment between ilium and sacrum. They resemble most closely the geographically distant *C. oxyrhina*. Similarly, AMNH 79961 (S-V 27.4 mm) from Soliabeda, Chimbu Province (Fig. 4) falls into the size range of *C. fistulans*, but the site is 250 km to the west of the known range of that species. Each instance may represent either a range extension or a new species, but either more specimens to allow a study of variation or call data are needed before their identity can be resolved.

RMNH 5256 and 5269 from Timena River, Irian Jaya are tiny (S-V 15.3 mm, 15.7 mm), and appear juvenile. It is therefore impossible to determine their specific identity.

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specimens, and to him my debt is incalculable. Zweifel also provided the map on which Fig. 4 is based. M. J. Tyler and M. Davies read the manuscript and provided valuable criticisms. Much of the work was undertaken whilst I was a Visiting Research Fellow in the Department of Zoology, University of Adelaide.

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**ON THE TAXONOMIC STATUS OF THE AUSTRALIAN CHITON
PARACHITON VERCONIS (COTTON & WEEDING, 1939)
(MOLLUSCA: POLYPLACOPHORA: LEPTOCHITONIDAE)**

BY K. L. GOWLETT-HOLMES

Summary

BRIEF COMMUNICATION

ON THE TAXONOMIC STATUS OF THE AUSTRALIAN CHITON *PARACHITON VERCONIS* (COTTON & WEEDING, 1939) (MOLLUSCA: POLYPLACOPHORA: LEPTOCHITONIDAE)

Cotton & Weeding (1939)¹ described the chiton, *Parachiton verconis*, from a single posterior valve dredged in 1909 off St Francis Island, South Australia. No complete specimen of this form has been recorded and, although the name has been adopted by various authors²⁻⁶, they note its close resemblance to the eastern Australian species *Leptochiton* (*Parachiton*) *puppis* Hull, 1923, and Kaas & Van Belle⁶ suggest that it may be a subspecies of it. Two complete specimens of *P. verconis* collected in South Australia have been located recently, providing the opportunity to compare it with *L. (P.) puppis*; it is apparent that the two forms are conspecific.

The material reported here is deposited in the Australian Museum, Sydney (AM), and the South Australian Museum, Adelaide (SAM). Spirit material is preserved in

2% formaldehyde/propylene glycol solution. The radula was prepared for examination under a scanning electron microscope (SEM) after the method of Bandel⁷.

Systematics

Family Leptochitonidae Dall, 1889

Genus *Leptochiton* Gray, 1847

Subgenus *Parachiton* Thiele, 1909

Leptochiton (*Parachiton*) *puppis* (Hull, 1923)

FIGS 1-3

Parachiton puppis Hull, 1923⁸, p. 158, pl. 24, figs 1-5; Iredale & Hull, 1925⁹, p. 344, pl. 39, figs 15-19; Iredale & Hull, 1927¹⁰, p. 46, pl. 6, figs 15-19.

Lepidopleurus puppis: Ashby, 1924¹¹, p. 322.

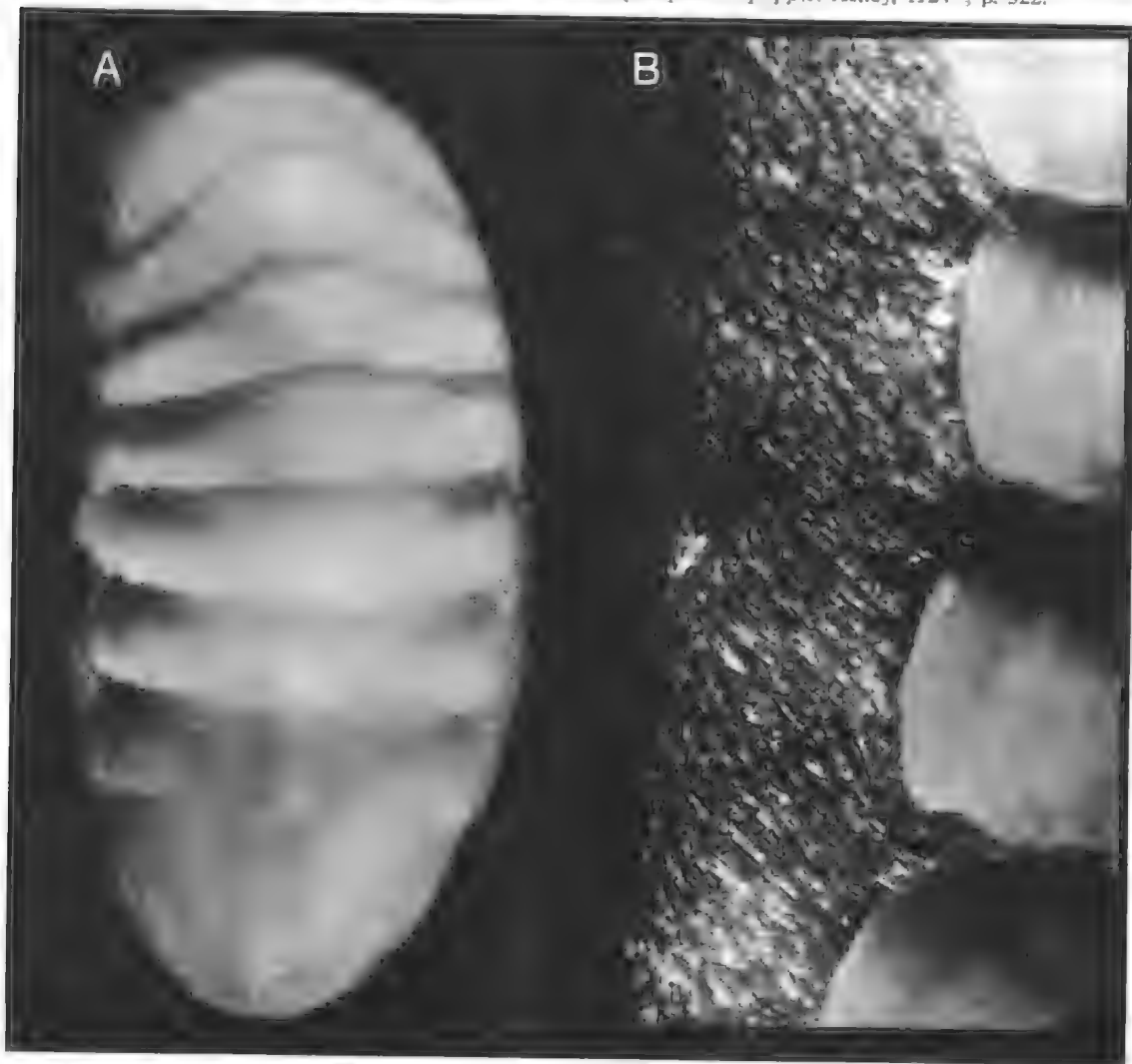


Fig. 1. *Leptochiton* (*Parachiton*) *puppis* (SAM D18415). A. whole specimen, x 8.5; B. detail of girdle, x 30.

Parachiton verconis Cotton & Weedling, 1939¹, p. 183, pl. 7, fig. 2; Cotton & Godfrey, 1940², p. 482, fig. 464; Cotton & Godfrey, 1940³, p. 22; Cotton, 1964¹, p. 21, fig. 12.

Leptochiton (Parachiton) puppis: Kaas, 1977¹², p. 85; Kaas & Van Belle, 1980³, p. 107; Kaas & Van Belle, 1985¹⁴, p. 169, fig. 78, map 25.

Leptochiton (Parachiton) verconis: Kaas, 1977¹², p. 85; Kaas & Van Belle, 1980³, p. 139; Kaas & Van Belle, 1985¹⁴, p. 177, fig. 83, map 25.

Leptochiton verconis: Zeidler & Gowlett, 1986¹³, p. 111.

Material examined: Types: *Parachiton puppis*: Holotype (AM C49540) and paratype (AM C149663), Bottle and Glass Point, Vacluse, N.S.W., coll. A.F.B. Hull & W. Barnes. *Parachiton verconis*: Holotype (SAM D11689) (single posterior valve), St Francis Id, Nuyts Archipelago, S. Aust., dredged in 27–37 m (15–20 fm), coll. J. C. Verco, 1909.

Other material: SAM D10670 (1) from Bottle and Glass Rocks, Vacluse, N.S.W., coll. E. Ashby, 25.ix.1923; SAM D14929 (1) from off Brighton, S. Aust., dredged in 18 m, coll. M. Tilbrook, 8.vi.1968; SAM D18415 (1) from off Monument Hill, northern Spencer Gulf, S. Aust., (32°50'00"S, 137°50'52"E), using Smith-McIntyre Grab dredge in 11 m, coll. E. Oks, ix.1987.

Description: A specimen from Bottle and Glass Rocks, Vacluse, N.S.W., was described in detail⁹. Supplementary data:-

Small chiton to 18 mm (Fig. 1A). Tegmentum with aesthetes arranged in semicircular groups, usually of five aesthetes, on each of the coalescing pustules of the lirae, with the semicircles opening anteriorly (Figs 2A, 2B). Posterior valve with postmucronal slope steep, straight to slightly concave (Fig. 3).

On the dorsal girdle, the "gothic candle-like" spicules of Kaas & Van Belle¹⁴ are random, close-set, becoming larger and denser toward valves in fresh specimens (Fig 1B). These spicules are easily dislodged, and usually are missing from specimens from older collections.

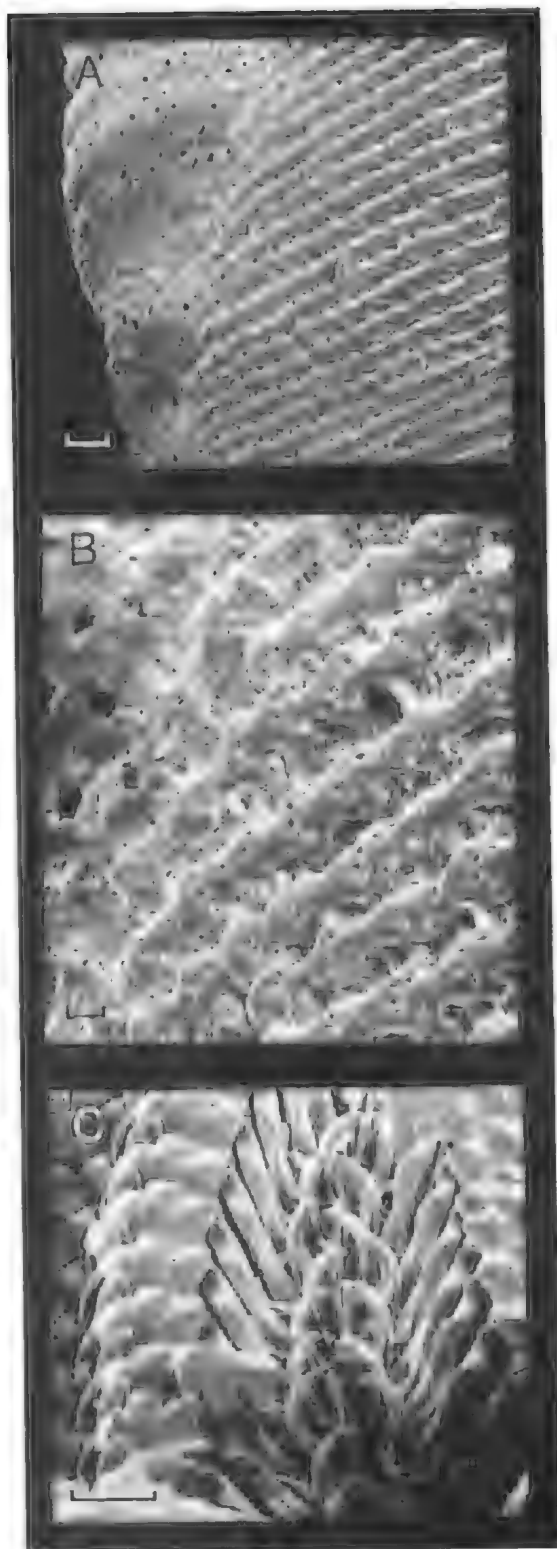
Radula (Fig. 2C) with narrow, very elongate central teeth, each with median longitudinal ridge, apical edge of head irregular; first lateral teeth narrow, very elongate, strongly curved; major lateral teeth elongate, narrow basally, with wide, bluntly tricuspidate heads, central cusp longest.

Ctenidia large, merobranchial, adanal without interspace, with 10–17 on each side.

Habitat On and under stones, pebbles and shell fragments in sand, intertidal to at least 27 m depth.

Range South-eastern Australia, from Vacluse, central N.S.W. to Nuyts Archipelago, western S. Aust.; not recorded from Vic. or Tas.

Fig. 2. *Leptochiton (Parachiton) puppis*. A. tegmentum surface showing coalescing pustules and aesthetes, paratype, scale bar = 100 μ m (AM C149663); B. detail of tegmentum surface showing aesthetes, paratype, scale bar = 20 μ m (AM C149663); C. radula, scale bar = 100 μ m (SAM D18415).



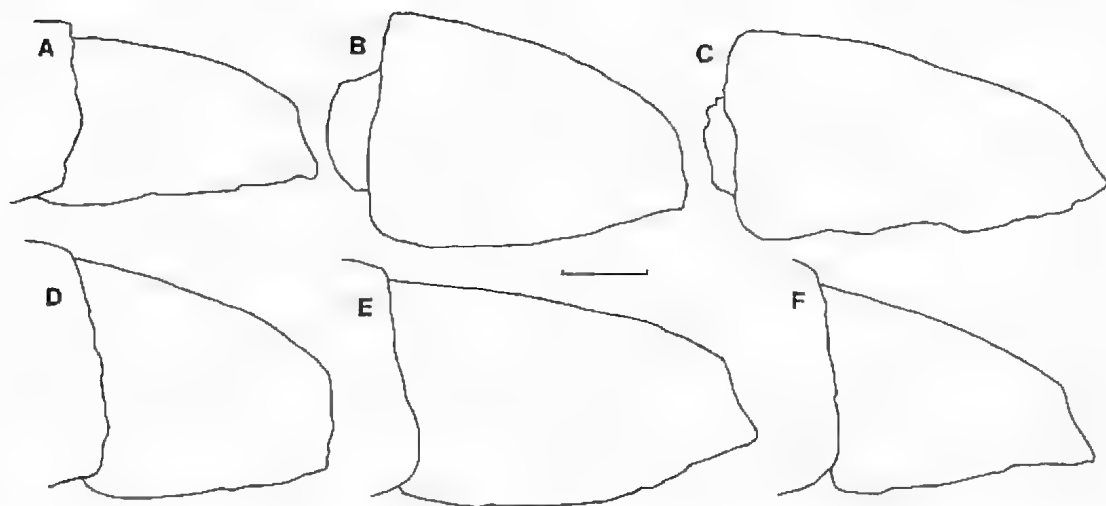


Fig. 3. *Leptochiton (Parachiton) puppis*. Posterior valve lateral profiles. A. holotype (AM C49540); B. paratype (AM C149663); C. *Parachiton verconis* holotype (SAM D11689); D. (SAM D10670); E. (SAM D14929); F. (SAM D18415); scale bar = 1 mm.

Remarks The main difference between *verconis* and *puppis*¹ is fewer granulate lirae on the posterior valve in *verconis*, which was shown to be incorrect by Kaas & Van Belle⁶. The only other difference given between the two forms was the shape of the posterior valve postmucronal slope: concave in *verconis*, straight in *puppis*. An examination of the available specimens has shown intergrading between the two extremes (Fig. 3), so this feature is not a consistent difference. Accordingly, *Parachiton verconis* Cotton & Weeding, 1939, is

considered a synonym of *Leptochiton (Parachiton) puppis* (Hull, 1923).

Kaas & Van Belle⁶ record *L. (P.) puppis* from Port Stephens, N.S.W., citing a record in Ashby¹¹. However, the specimen referred to there (probably SAM D10670) is stated to have been collected at Bottle and Glass Rocks, Vacluse, so that record is in error.

I thank Mr I. Loch (AM) for the loan of the type specimens of *Parachiton puppis*. The photographs were taken by Mrs J. Forrest and Ms A. Renfrey (SEM).

¹Cotton, B. C. & Weeding, B. J. (1939) Trans. R. Soc. S. Aust. 63(2), 180-99, pl. 7.

²Cotton, B. C. & Godfrey, F. K. (1940) "The Molluscs of South Australia, Part II: Scaphopoda, Cephalopoda, Aplacophora and Crepidopoda." (S. Aust. Govt Printer, Adelaide).

³Cotton, B. C. & Godfrey, F. K. (1940) Malac. Soc. S. Aust. 2, 1-32.

⁴Cotton, B. C. (1964) "South Australian Mollusca: Chitons." (S. Aust. Govt Printer, Adelaide).

⁵Kaas, P. & Van Belle, R. A. (1980) "Catalogue of Living Chitons (Mollusca: Polyplacophora)". (W. Backhuys, Rotterdam).

⁶Kaas, P. & Van Belle, R. A. (1985) "Monograph of

living chitons (Mollusca: Polyplacophora). Vol. 1. Order Neoloricata: Lepidopleurina". (Brill, Leiden).

⁷Bandel, K. (1984) Zool. Verhandl., Leiden 214, 1-188.

⁸Hull, A. F. B. (1923) Aust. Zool. 3, 157-166, pls 24-26.

⁹Iredale, T. & Hull, A. F. B. (1925) Aust. Zool. 4(2), 75-111, pls 9-12.

¹⁰Iredale, T. & Hull, A. F. B. (1927) "A Monograph of the Australian Loricates (Phylum Mollusca-Order Loricata)." (R. Soc. N.S.W., Sydney).

¹¹Ashby, E. (1924) Trans. R. Soc. S. Aust., 48, 313-22, pl. 31.

¹²Kaas, P. (1977) Basteria 41, 81-86.

¹³Zeidler, W. & GOWLETT, K. L. (1986) Rec. S. Aust. Mus. 19(8), 97-115.

***LEIOLOPISMA TRILINEATUM* (GRAY, 1838), AN ADDITION TO THE
HERPETOFAUNA OF SOUTH AUSTRALIA**

BY MARK N. HUTCHINSON

Summary

BRIEF COMMUNICATION

LEIOLOPISMA TRILINEATUM (GRAY, 1838), AN ADDITION TO THE HERPETOFAUNA OF SOUTH AUSTRALIA

Two scincid lizards, *Leiolopisma trilineatum* (Gray, 1838) from southwestern and southeastern Australia and Tasmania, and *L. platynotum* (Peters, 1881) from temperate eastern Australia (Fig. 1), have been recognised as close relatives, united as the *L. trilineatum* species group¹. The southern Australian taxon, *L. trilineatum*, was subsequently divided into two species². The name *L. trilineatum* was restricted to the southwest, and populations from southeastern Australia were assigned to *L. duperreyi* (Gray, 1838). The *L. trilineatum* species group belongs to the *L. baundini* group, one of two assemblages within Australia's *Leiolopisma* radiation², and has also been regarded as the sister lineage to *Problepharus* and *Morethia*¹.

South Australian populations, distributed in coastal and temperate habitats from Kangaroo Island to the Victorian border, all conform to *L. duperreyi* in having well developed lateral striped patterning, including a white midlateral stripe edged below by a black line, and a narrow but prominent white dorsolateral line along the middle of scale row 3 from the level of the ear to the base of the tail. These populations represent the western limit of *L. duperreyi*, while the eastern limit of *L. trilineatum* is at the western end of the Great Australian Bight (Western Australian Museum [WAM] R91637, Billbunya Dunes, west of Point Culver). No records of either species had been made from the intervening, arid terrain of the Bight^{1,3,4,5}.

During April-May 1988, two specimens of the *L. trilineatum* species group were collected on the Jussieu Peninsula, at the tip of the Eyre Peninsula. The first, (Museum of Victoria) NMV D60954, a female of 62 mm SVL, from Wonna, at the eastern end of Sleaford Bay, was collected by S. Dounell and G. Armstrong. The second, NMV D50955, male of 63 mm SVL, from just south of Taylor's Landing on the east coast of the Jussieu Peninsula, was collected by the author and D. Pollock. Both specimens were collected from clumps of a coastal shrub, *Calocephalus harrisi* (Asteraceae), growing on rocky ground a few metres from coastal cliff edges. *Calocephalus* forms rounded hummocks up to 80 cm high and 1 m or more in diameter and, in this area, provides a humid, shaded refuge for a variety of reptiles.

In colour pattern, the two specimens conform to *L. trilineatum*, not the nearby Kangaroo Island *L. duperreyi*, and thus represent the first S. Aust. records for *L. trilineatum sensu stricto*. The lateral pattern is diffuse with no dark-edged white midlateral stripe, and a relatively poorly contrasting pale brown dorsolateral stripe which is broad (running along the outer half of scale row 3 and the upper third of scale row 4) and fades posteriorly. The dorsal scale rows have dark pigment at their corners, forming a series of narrow dark dorsal lines, but there is no strongly developed vertebral black stripe (typical of *L. duperreyi*).

In scalation, the two specimens diverge from the redescription² in the number of paravertebral scales:

Specimens of *L. trilineatum* from between Augusta and Esperance (the centre of the species' range) examined by Greer differed from *L. duperreyi* in that paravertebral scale counts within sexes showed minimal overlap. Male *L. trilineatum* ranged 54-59 (\bar{x} 56.3) paravertebrals, compared with 57-62 (\bar{x} 59.6) for male *L. duperreyi*, while in females the counts were 56-61 (\bar{x} 59.8) and 62-66 (\bar{x} 63.1), respectively. Greer² standardized the method of counting paravertebral scales, starting at the first scale behind a line joining the back of the thighs and finishing with the enlarged nuchal adjoining the parietal. Using this method, the Eyre Peninsula male has 60 paravertebrals and the female 61, so that the male falls in Greer's *duperreyi* range of values. However, examination of specimens from the most geographically proximate W.A. populations of *L. trilineatum* (east of Esperance) shows that males can range as high as 60 paravertebrals (WAM R68223, Mondrain Is, Recherche Archipelago), and females as high as 63 (WAM R41927, Base of Mt Le Grand).

The observation that the paravertebral scale count differences are not as absolute as first thought does not diminish the likelihood that the eastern and western populations represent two distinct species. The great consistency in colour pattern along more than 1,000 km of the Bight coastline, followed by the abrupt switch between the Eyre Peninsula and the Kangaroo Island population, plus the fact that paravertebral counts are still significantly different between the two, argues for their genetic independence.

In life, neither specimen had red throat colouring. The presence of bright colour patches in *Eugongylus* group skinks may or may not be sexually significant, and the status of this character in the *L. trilineatum* species group is confused. Greer¹ reported that red colouring occurs in "both sexes and all age groups" in the species of the *L. trilineatum* group, and later² noted that *L. trilineatum* he collected appeared to vary seasonally or geographically: specimens collected in mid October from Esperance lacked red colouring, while the colour was present in all specimens ($n = 9$, sex not specified) collected four days later from Augusta. In my experience, however, red throat colouring is found only in mature males, not females, of all three species of the *L. trilineatum* group, and immatures of at least one species also have red colouring on the sides of the jaws and neck. The distribution of red throat colouring is not only of intrinsic interest, but may also have a bearing on the relationships of the *L. trilineatum* species group. Table 1 summarizes the known occurrence of red colour patches in the members of the *L. trilineatum* species group.

In *L. duperreyi*, at least in Victoria and Tasmania, all juveniles of both sexes hatch with pink to orange-red patches on each side of the neck and over the ear opening (Rounsevell⁶ and pers. obs.). This colour is lost at sexual maturity, which occurs at about 50-55 mm snout-vent length^{7,8}. Breeding males (late spring-summer) develop bright scarlet throat colouring on the chin and gular scales,

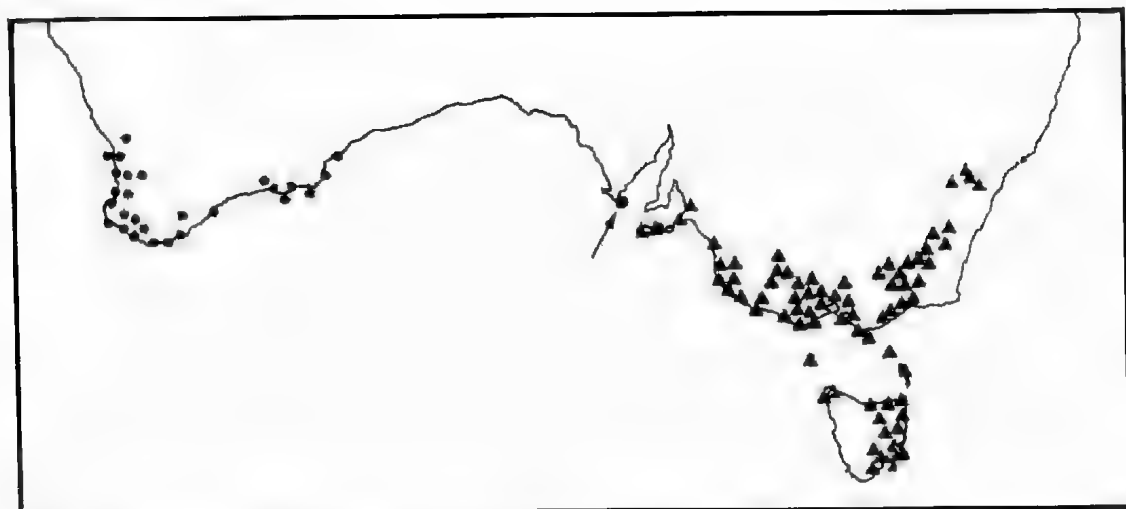


Fig. 1. Distributions of *Leiolopisma trilineatum* (solid circles) and *L. duperreyi* (triangles). Arrow indicates Jussieu Peninsula area where S.A. *L. trilineatum* were collected (after Greer 1980).

but not extending to the "juvenile" position around the ears. Females do not redevelop red colouring. Observations on the presence or absence of red colouring are not available for juveniles of *L. trilineatum* and *L. platynotum*, breeding female *L. trilineatum* and non-breeding male *L. platynotum*.

A gradient in the timing of reproductive activity (and the development of red throat colouring) in *L. trilineatum* has been noted⁹, with populations in warmer parts of the species range (around Perth) breeding earlier (mid to late spring) than more southerly populations (summer). This suggests that the observation of variation in *L. trilineatum* throat colouring may be due to climatic differences across the area, such that specimens from the cooler area (Esperance) were not yet in breeding condition and so lacked red colouring.

Thus the evidence available to me strengthens the hypothesis of a close relationship between the *L. trilineatum* species group and *Morethia*¹, since in both taxa, red pigmentation is limited in adults to males. Another point helping to reinforce this relationship is the presence of occasional scale anomalies that link the two

groups. In the female *L. trilineatum* from Wanna (NMV D50954), the postnasal scales are distinct and there is a partial posterior separation of the supranasals, character states retained in most *Morethia* but usually absent in the *L. trilineatum* species group. As Greer suggested, based on a similarly aberrant specimen of *L. platynotum*, the supranasal and postnasal scales have apparently been lost via fusion with the nasal. In one of the W.A. *L. trilineatum* examined (WAM R77956, 13 km W of Point Dempster), the interparietal shield, which is usually distinct in the *L. trilineatum* group, has fused with the single frontoparietal, forming the single large plate typical of *Morethia*.

The presence of *L. trilineatum* on the tip of the Eyre Peninsula adds to a group of reptiles apparently widespread during glacial times across the cool, semi-arid plain exposed along the southern margin of the Australian continent, but reduced to disjunct or relictual near-coastal pockets since the post-glacial rise in sea level. This group of species includes *Egernia multiscutata*, *Hemiergis peronii*, *Leiolopisma trilineatum*, *L. baudini*, *Lerista arenicola*, *L. dorsalis*, *L. terdigitata*, *Gemmatophora* (= *Amphibolurus*) *norrisi*, *Notechis ater*, *Drysdalia mastersi*,

TABLE 1. Distribution of red colour markings in members of the *L. trilineatum* species group. (-): absent; (?): not known.

Species	males		females		juveniles
	breeding	non-breeding	breeding	non-breeding	
<i>L. duperreyi</i>	throat	—	—	—	sides of neck and jaws
<i>L. platynotum</i>	throat and sides of neck	?	—	—	?
<i>L. trilineatum</i>	throat and sides of neck	—	?	—	?

and possibly others such as *Aprasia striolata* and some species pairs like *Tympanocryptis adalaidensis* — *T. diemensis* and *Egernia luctuosa* — *E. conventryi*. *L. trilineatum* is like several of these species in that it was first believed to be restricted to W.A. but has since proven to be patchily distributed well to the east. In most biogeographic schemes for southern Australia, a southwestern region encompassing the higher rainfall areas is usually shown terminating at the beginning of the Great Australian

Bight (Israelite Bay area), while a southeastern (Bassian) region extends west to Kangaroo Island or the southern tip of the Eyre Peninsula^{9,10,11}. In fact the pattern of reptile distributions along the southern coast now suggests that the Eyre Peninsula area, rather than the western end of the Bight, represents the major point of changeover from a southwestern to a southeastern reptile fauna.

¹Greer, A. E. (1980) *Rec. Aust. Mus.* 33, 89–122.

²Greer, A. E. (1982) *Ibid.* 34, 549–573.

³Rawlinson, P. A. (1974) Biogeography and ecology of the reptiles of Tasmania and the Bass Strait area. In Williams, W. D. (Ed.), "Biogeography and Ecology in Tasmania", (W. Junk, The Hague).

⁴Schwaner, T. D., Miller, B. & Tyler, M. J. (1985) Reptiles and amphibians. In Twidale, C. R., Tyler, M. J. & Davies, M. (Eds), "Natural History of Eyre Peninsula" (Royal Society of South Australia, Inc., Adelaide).

⁵Storr, G. M., Hanton, T. M. S. & Harold, G. (1981) *Rec. West. Aust. Mus.* 9, 23–39.

⁶Rounsevell, D. (1978) *Tasmanian Nat.* (52), 1–2.

⁷Pengilley, R. K. (1972) Systematic relationships and ecology of some lygosomine lizards from southeastern

Australia. Unpubl. PhD thesis, Dept of Zoology, A.N.U., Canberra.

⁸Hudson, S. C. (1988) Phalangeal growth rings as a method of aging for scincid lizards, and its application to the study of life history in *Leiopisma entrecasteauxii* and *L. duperreyi*. Unpubl. B.Sc.(Hons) thesis, Dept of Zoology, La Trobe University, Bundoora.

⁹Dell, J., pers. comm., January, 1989.

¹⁰Keast, A. (1959) The reptiles of Australia. In Keast, A., Crocker, R. L. & Christian, C. S. (Eds), "Biogeography and Ecology in Australia", (W. Junk, The Hague).

¹¹Heatwole, H. (1987) Major components and distributions of the terrestrial fauna. In Dyne, G. R. & Walton, D. W. (Eds), "Fauna of Australia, Vol. 1A, General Articles", (Aust. Govt Publ. Serv., Canberra).

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**A NEW SUBSPECIES OF THE SEA URCHIN *PERONELLA LESUEURI*
FROM THE QUATERNARY OF SOUTH AUSTRALIA**

BY N. S. PLEDGE & T. SADLER

Summary

BRIEF COMMUNICATION

A NEW SUBSPECIES OF THE SEA URCHIN *PERONELLA LESUEURI* FROM THE QUATERNARY OF SOUTH AUSTRALIA

The laganid sea urchin, *Peronella lesueuri*, currently lives in the seas from the Maldives to New Zealand and north to Hong Kong. On the Australian coastline it occurs from Albany in Western Australia, north around the tropical coast to Port Denison (Bowen, Queensland) in the east.¹ It is known from the Miocene of Java and occurs in several places from the Pliocene in the Indo-Australian area.² It has not been recorded previously, extant or fossil, in South Australia.

Over the past few years, excavations for foundations and site works for the new Northern Power Station at Port Augusta have resulted in a variety of Quaternary fossils being brought to the South Australian Museum for identification. Amongst them have been a number of large sand dollar sea urchins, which have been acquired from several sources, most notably Messrs John Turner and Des Page.

These echinoids were derived from a creamy yellow-grey silty clay dredged during excavation of the large cooling water channel "... from a depth of about 7-8m in yellowish mud, below a black mud, and above a clean sand and hard, brown clay. The bottom of the channel is limestone at about 14m".³ To determine more accurately the stratigraphic position of the echinoids, access was gained to the study reports⁴ on the geology of the new power station site and to the core held in the S.A. Dept Mines and Energy Core Library.

The sequence can be matched in some of the cores drilled, though not all because of rather rapid lateral changes concomitant with its nearshore estuarine setting. The matrix matches those segments of the bore-cores interpreted as Bakara Calcrete although no direct evidence of echinoid remains was present. It is probably equivalent to the "soft mottled sandy clay"⁵ just below the Glenville Formation.

Shells of the Sydney blood cockle *Anadara trapezia* occur in the sand dredged with the echinoids. Unfortunately they are not found together in the same lump of matrix and their true relationship has been obscured by excavation. *A. trapezia* is abundant in the Glenville Formation elsewhere, equivalent of the Bakara Calcrete.⁶ The age of the echinoids is therefore considered to be Late Pleistocene, possibly of the last Pleistocene high sea level.

Nine mostly complete specimens and numerous segments have been collected (Table 1).

SYSTEMATICS

Class Echinoidea

Order Clypeasteroidea A. Agassiz

Family Laganidae A. Agassiz

Genus *Peronella* Gray

Peronella lesueuri (L. Agassiz, 1841)

Peronella lesueuri *augusta* subsp. nov.

Laganum lesueuri L. Agassiz, 1841: 116, pl. 24, figs 3-6
Peronella lesueuri A. Agassiz, 1872: 148.⁶

Holotype: P24854, South Australian Museum, comprising a complete test.

Diagnosis: Medium to large size, thin, elongate, oval; broadest just anterior of the apical disc, tapered behind, orally slightly concave. Notched or tangentially flattened at marginal ends of ambulacra. Apical area raised, almost central; petals narrow elongate, open, length 0.5-0.7 of radius, petals reduced to single pores apically and end some distance from the genital pores, between paired pores miliary tubercules only; four genital pores all within the madreporite; the posterior two placed wider apart. Peristome anterior of centre; ambulacral food grooves short, with the anterior groove 10% of length on the holotype. Periproct 6% of length from posterior margin. Tubular ornamentation fine, regular, twice as dense dorsally as ventrally.

Comment: Morphologically, *Peronella lesueuri* appears to be quite variable and although two varieties have been described⁷ the species is clearly in need of revision. The specimens described here differ consistently from *P. lesueuri lesueuri* in that they are concave orally, tapered behind, have a test margin that borders on the thin extreme, and the petals reduce to single pores apically.

These specimens differ from *P. lesueuri* var. *rostrata*, extant in the Philippines, in that they are broader relative to length, the tapering of the test posteriorly does not reach the extremes of this variety, nor do the series of pore pairs reach the genital pores and the genital pores are within the madreporite rather than on the margin.

TABLE 1. Measurements of *Peronella lesueuri* *augusta* subsp. nov. N, collection number, South Australian Museum; L, longitudinal diameter; T, transverse diameter; H, height. All measurements in millimetres.

N	L	T	H
P24854 (type)	80.0	70.9	11.2
P24852	68.5	58.1	9.0
P24562	85.1	75.5	11.3 (est)
P24659	79.4	72.2	11.7
P24664	39.6	35.7 (est)	
P24850	51.8	45.7	9.8
P24851	40.3	37.6	5.5
P24853	86.2	78.1	11.8
P24855	71.3	60.5	7.2

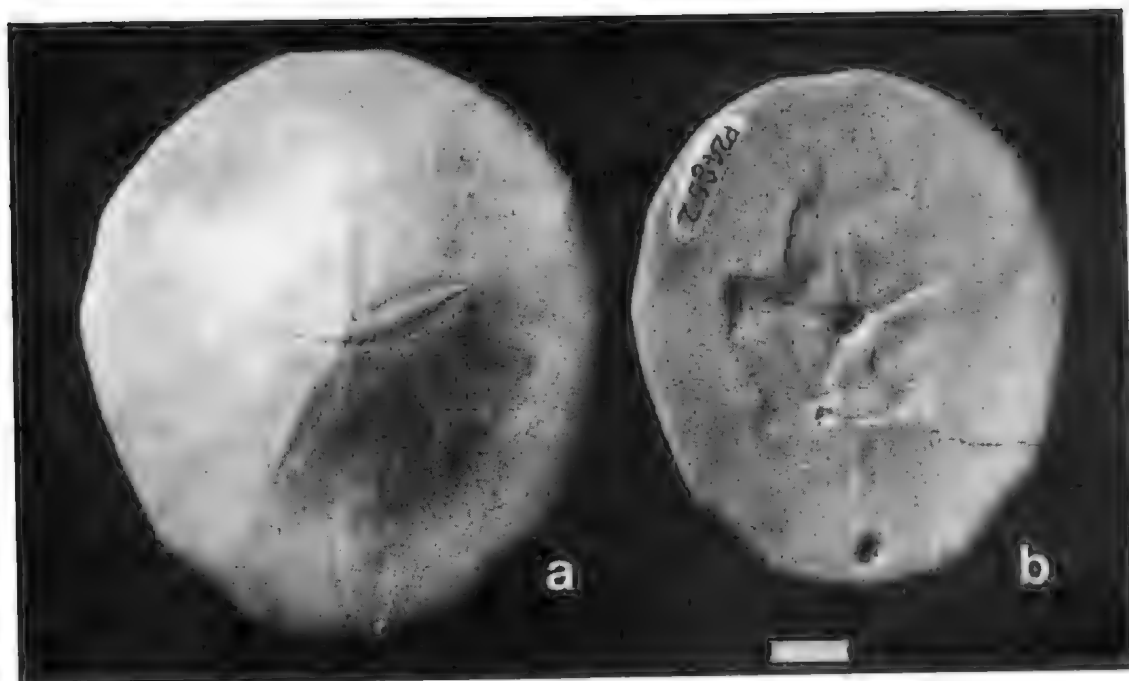


Fig. 1. *Peronella lesueuri augusta* subsp. nov. (a) apical view SAM P24854, (b) adapical view SAM P24852, Scale = 1cm.

The specimens differ from *P. lesueuri* var *gadiana*, extant in Singapore and the Strait of Malacca, in that the shape of the test is elongate rather than rounded, the

margin being thin, the shape of the pore pairs and that they are separated only by miliary tubercules rather than interrupted by primary tubercules.

- ¹ Mortensen, T.H. (1948) "A Monograph of the Echinoidea." Part IV(2), Clypeastroida. (Reitzel, London.)
- ² Durham, J.W. (1955) Univ. Calif. Public. Geol. Sci., 31, 73-198.
- ³ Turner, J. (1984) Pers. comm. 21.vi.1984.
- ⁴ Selby, J., Waterhouse, J.D. & Jones, G. (1976) Proposed Northern Power Station, Playford South site, Port Augusta. Preliminary geological and botanical investigations. Unpub. Report. S. Aust. Dept Mines. Rept. Bk. 76/69.

- ⁵ Selby, J. & Milner, G. (1981) Q. Geol. Notes, Geol. Surv. S. Aust. 77, 1-7.
- ⁶ Firman, J. (1969) Quaternary Period. In Parkin, L.W. (ed. "Handbook of South Australian Geology." (Geol. Surv. S. Aust., Adelaide.)
- ⁷ Agassiz, L. (1841) "Monographies d'echinodermes: des Scutelles." (Neuchatel en Suisse.)
- ⁸ Agassiz, A. (1872) "Illustrated Catalogue of the Museum of Comparative Zoology at Harvard College, No. 7. Revision of the Echini." (Univ. Press, Cambridge.)

**TWO REPLACEMENT NAMES IN CASTIARINA
(BUPRESTIDAE: COLEOPTERA)**

BY MARK N. HUTCHINSON

Summary

BRIEF COMMUNICATION

TWO REPLACEMENT NAMES IN *CASTIARINA* (BUPRESTIDAE: COLEOPTERA).

The elevation of *Castiarina* to genus¹ and the transfer of *Hypostigmodera variegata* Blackburn (1892)² to it, has created the need of a replacement name for one species. *Stigmodera (Castiarina) variegata* Barker (1983)³ becomes a secondary homonym. I propose that the latter taxon be replaced with *C. interstincta*, derived from *interstinctus* L., "variegated".

In addition *Stigmodera (Castiarina) deliciosa* Barker (1988)⁴ is a primary homonym of *Stigmodera deliciosa* Kerremans (1898)⁵ and I propose the younger name be replaced with *C. beatrix*, derived from *beatrix* L., "she that makes happy".

¹Gardner, J. (1990) *Invert. Taxon.* 3, 291–361.

²Blackburn, T. (1892) *Trans. R. Soc. S. Aust.* 15, 207–291.

³Barker, S. (1983) *Trans. R. Soc. S. Aust.* 107, 139–169.

⁴Barker, S. (1988) *Trans. R. Soc. S. Aust.* 112, 133–142.

⁵Kerremans, C. (1898) *Annls Soc. ent. Belg.* 42, 113–182.

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**NEW SPECIES AND A NEW GENUS OF MICRO-CADDISFLY FROM
NORTHERN AUSTRALIA, INCLUDING THE FIRST AUSTRALIAN
RECORD OF THE TRIBE STACTOBIINI (TRICHOPTERA:
HYDROPTILIDAE)**

*BY A. WELLS**

Summary

Twenty-two further species are recognised in the Australian Hydroptilidae, all from northern Australia and, with the exception of *Oxyethira bogambara*, all newly described. For the first time a stactobiine species (in *Chrysotrichia*) is recorded and also a new monotypic genus, *Jabitrchia* gen. nov., probable sister group to *Oxyethira*. Other new species include two in *Oxyethira*, six in *Hellyethira*, two in *Acritoptila*, one in *Orphninothrichia* and eight in *Orthotrichia*. Information is given on immatures of several species, some new and others established. For the latter, new data on ranges also are supplied.

KEY WORDS: Taxonomy, Trichoptera, Hydroptilidae, Stactobiini, Northern Australia, new genus.

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by A. WELLS*

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KEY WORDS: Taxonomy, Trichoptera, Hydroptilidae, Stactobiini, Northern Australia, new genus

Introduction

The basic composition of the Australian Hydroptilidae (Trichoptera) appeared to be known until recent intensive collecting in northern Australia revealed several new elements, as well as more species in established groups. Now, an Oriental-New Guinean genus in a tribe hitherto unknown in Australia and a new monotypic genus are reported. Both represent significant additions to the fauna.

Wells (1986¹) commented on the relatively restricted nature of Australian Hydroptilidae, apparently comprising only two Hydroptilinae tribes, Hydroptilini and Orthotrichiini. Several genera in the tribe Stactobiini were known from SE Asia, but none from Australia or New Guinea. More recently, three stactobiine genera have been reported from New Guinea (Wells 1990b), and now a species in *Chrysotrichia* Schmid is described from NE Australia.

Another new species from northern Australia keys to *Hydroptila* Dalman with which it shares the derived features (Wells 1986¹) of tibial spur formula 0,2,4, and ocelli absent. Yet in general wing shape and venation, form of male and female genitalia, and presence of abundant *sensilla auricillica* on antennal segments of males, it more closely resembles members of *Oxyethira* Eaton, which has three ocelli and usually tibial spurs 0,3,4. Arguments are given for the establishment of a new genus, perceived as the sister group of *Oxyethira*, and the presence of this taxon is discussed in

relation to representation of *Oxyethira* subgenera in Australia.

Among others described in this paper, is a species in *Orphninothrichia* Mosely, an endemic genus previously unknown to the northwest of the Great Dividing Range, although common and diverse in the southeast and occurring in the south-central region. A torrenticolous group, it is probably not surprising to find a member, possibly a component of a relictual Gondwanan fauna, in a small monsoon forest stream at the foot of the Kakadu Escarpment. From this same locality, a species is referred to *Oxyethira* (*Trichoglene*), the most primitive of the *Oxyethira* subgenera; it most closely resembles a New Caledonian species, *Oxyethira insularis* Kelley.

Additional to the above, are a second and highly irregular new species in *Oxyethira*, and the first Australian records of the widespread Oriental *O. bogambara* Schmid. Descriptions are given also of new species in the almost-cosmopolitan *Orthotrichia* Eaton, and in the Australian-E Asian *Hellyethira* Neboiss, genera which together comprise more than half the Australian hydroptilid fauna; and two new species are referred to the Australian-New Caledonian genus, *Acritoptila* Wells. Information on immatures is supplied when available, and is included for several established species, previously unknown from larvae and/or pupae. Ranges of these species are extended.

Twenty-one new species are described, and with *O. bogambara*, they raise the Australian Hydroptilidae to 121; tribal representation increases to three, all in the subfamily Hydroptilinae. Compared with about 340 species in all other trichopteran families in Australia (Neboiss 1988), hydroptilids appear extraordinarily well represented. However, work in progress on other families (e.g.

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¹ Wells, A. (1986) The systematics and biogeography of the Australian Hydroptilidae (Trichoptera). Ph.D. thesis, University of Adelaide (unpubl.).

Ecnomidae, Leptoceridae, and Hydropsychidae: Cartwright, Neboiss, St Clair & Dean in prep.) will shift the emphasis and result in a more realistic picture of the fauna.

Materials and Methods

Methods follow those of Wells (1979a, 1990a). All holotypes and some paratypes were prepared as permanent slide mounts in Canada balsam.

Material studied includes light trap collections from Yuccabine Creek, NE Queensland (Benson & Pearson 1988), and Alligator Rivers region, Northern Territory, collected from 1985–1989. Samples of immatures were collected from the latter area, and for several species larvae have been associated with adults using pharate adults, larval exuviae and cases. Reappraisal of Benson & Pearson's (1988) material has resulted in changes to several identifications and these are indicated for the species involved. One new species from NW Western Australia is described.

No keys to genera or species are given as this is essentially a miscellaneous set of species.

Depositories are abbreviated as follows:

Museum of Victoria, Melbourne (NMV); Museum and Art Galleries of the Northern Territory, Darwin (NTM); National Museum of Natural History, Washington, DC, (USNM); West Australian Museum (WAM).

Systematics

Chrysotrichia Schmid

Chrysotrichia Schmid, 1958, p. 54. Type species: *Chrysotrichia hatnagola* Schmid, by original designation.

Chrysotrichia ranges from Pakistan to New Guinea (Wells 1990b) and has been collected from beside slow, lowland streams (Schmid 1958) and faster first order streams (Wells 1990a, 1990b); larvae have been collected from rocks in streams. *Chrysotrichia australis* sp. nov. closely resembles *C. iomara* Wells from the Central and East Highlands provinces of New Guinea (Wells 1990b) and probably evolved from relatively recent emigrants to Australia.

Chrysotrichia australis sp. nov.

FIG. 1

Holotype: NMV, ♂, NE Qld, Yuccabine Creek, 1.1986, R. G. Pearson & L. J. Benson.

Diagnosis: Closely resembling *C. iomara* in form of male genitalia, but distinguished by inferior appendages more attenuate apically, and dorsal plate with a V-shaped apical cleft.

Description: Male. Anterior wing length, 1.3 mm. Genitalia, Fig. 1. Segment IX short. Dorsal plate elongate, longer than inferior appendages, a V-shaped cleft apically. Aedeagus slender, with paired spines apico-laterally. Inferior appendages broad-based, attenuate apically. Female and immatures unknown.

Distribution: Known only from the type locality, northeastern Qld.

Etymology: From the Latin – *australis* – southern, being the southern-most occurrence of the genus.

Jabitrichia gen. nov.

Type species: *Jabitrichia dostineti* gen. et sp. nov.

A new genus is erected to accommodate a species otherwise requiring considerable modification of the generic definitions of *Hydroptila* or *Oxyethira*, with each of which it shares some derived characters.

Jabitrichia gen. nov. shares with *Hydroptila* the apomorphic states of ocelli absent and tibial spur formula 0,2,4, as well as pattern of wing colour and form of thoracic scutellae. The long antero-lateral apodemes on abdominal segment IX, seen in male *Jabitrichia* gen. nov., are found in the Holarctic *lineoides* group in *Hydroptila* (Marshall 1979), although not in other groups. Yet, wings strongly attenuated, forewing without jugal lobe, antennal segments with dense *sensilla auricillica*, female genitalia in form of a modified oviscap, and particular reductions of male genital structures are apomorphies uniting the new genus with *Oxyethira*: spur formula 0,2,4 and aedeagus without titillator occur in some *Oxyethira*, although not together. The rounded or triangular forward projection of the antero-ventral margin of abdominal segment IX of males and the uniquely flask-shaped case of larva and pupa are autapomorphies of *Oxyethira* – as yet immatures of the new genus are unknown.

Spur number and presence of ocelli seem to be labile characters in Hydroptilidae, and in a somewhat different situation, with an ocelli-less New Guinean species which otherwise conforms with *Scelotrichia* Ulmer, I argued against establishing a separate genus (Wells 1990b). With this present species and *Hydroptila*, however, the synapomorphies are probably homoplastic. The closer association, indicated by sharing of derived states of more conservative characters, is thus with *Oxyethira*, and since several autapomorphic conditions can be recognised in each taxon, a new genus is erected.

Examination of characteristics of sub-genera in *Oxyethira* (see Kelley 1984) reveals resemblances between members of *O. (Dichoglene)* and

Jabirichia dostinei gen. et sp. nov. in general form of male genitalia. In lateral view, abdominal segment IX of each is similar in shape, although in ventral view the anterior margin of the segment is modified in *Oxyethira* while *Jabirichia* is closer to the primitive form for the family. According to Kelley (1984), some members of *O. (Trichoglene)* have lost the titillator on the aedeagus and in others it is present as a vestigial rod. The elaborately curved spine associated with the aedeagus of *Jabirichia* gen. nov. may be derived from the titillator.

O. (Trichoglene), the most primitive sub-genus in *Oxyethira* (Kelley 1984), is Australasian, occurring mainly in southern and eastern Australia, and in New Zealand and New Caledonia (Kelley 1989). A new species in this subgenus, *O. cornutata* sp. nov. described here from the Alligator Rivers Region in the north, most closely resembles a species from New Caledonia; this is the species in what I believe is a relictual fauna in the small monsoon forest stream. All other *Oxyethira* to the west of the dividing range in northern Australia are in the relatively highly derived *O. (Dampftrichia)*, several ranging from SE Asia through New Guinea to Australia. I have suggested previously (Wells 1987) that *O. (Trichoglene)* probably evolved in Gondwanaland and that in Australia *O. (Dampftrichia)* represents a relatively recent arrival from the Oriental region. *Jabirichia* gen. nov. appears to be the sister group of *Oxyethira*, surviving in northern Australia in what could well have been the habitat (Wells 1987) of their common ancestor – the warm, macrophyte-rich billabong that seasonally becomes a slow-flowing, warm stream. With the initial dichotomy, the ancestor of *Oxyethira* may have invaded cooler, faster-flowing systems.

Diagnosis: A sister group to *Oxyethira*, but differing in absence of ocelli, and in the male having slender anterior apodemes on segment IX.

Description: Adults. Head (Fig. 3) without ocelli, tentorium complete, tentorial arms reduced to fine threads medially, antennae of male with basal whorl of fimbriate hair and dense *sensilla auricillica* on flagellar segments. Thorax (Fig. 3) with mesoscutellum convex anteriorly, metascutellum triangular; libial spur formula 0,2,4; wings narrow, attenuate apically, vestiture fuscous anteriorly, pale cream posteriorly, anterior wing without jugal lobe, with fork 2 only (Fig. 2). Male genitalia: no mesal process on segment VII; segment IX short dorsally, with slender antero-lateral apodemes produced forwards (of form seen in *Stactobitini*), posterior margin forming stout lateral processes; dorsal plate (tergite X) and subgenital plates absent; aedeagus without titillator (may be represented by curved, elongate spine). Female genitalia a modified

oviscapt (as in *Oxyethira*); bursa copulatrix stoutly rounded.

Immatures unknown.

Comments: Known only from a single species collected at lights beside the slow-flowing inlet to a large, shallow billabong that supports a rich growth of macrophytes, northeastern N.T.

Etymology: Derived from Jabiru, the name of the township near the collecting locality.

Jabirichia dostinei gen. et sp. nov.

FIGS 2-7

Holotype: NTM, ♂, N.T., Gulungul Creek at inlet to Gulungul Billabong, 12°38'S, 132°53'E, 17.v.1988, Lt Tr., A. Wells & P. Suter.

Paratypes: NTM, ♀ (allotype), collected with holotype; NTM, NMV, 6 ♂♂, same loc., 11.iv.89, Wells & Suter; NMV, 1 ♂, Jabiru, Ranger Retention Pond 1, 20.v.88, Wells & Suter.

Diagnosis: As for the genus.

Description: Medium sized; pale, fuscous and cream. Male (Figs 2,3, 5-7). Anterior wing length, 1.8 mm. Antennae 32-segmented, segments elongate. Genitalia, Figs 5-7. Sternite IX about as long as wide, retracted within segment VIII; postero-lateral processes on segment IX stout, curved inwards, truncate apically; antero-lateral apodemes elongate, produced forwards into segment VI. Paired small sub-triangular ventro-lateral structures probably represent inferior appendages. Aedeagus swollen basally, constricted medially and expanded in distal half, a complex spine arises mesally, extends beyond apex to curve sharply anteriorly. Female. Length of anterior wing, 2.1 mm. Antennae 21-segmented, segments without *s. auricillica*. Genitalia, Fig. 4. Terminalla stout. Sternite IX broadly rounded posteriorly. Bursa copulatrix stout.

Immatures unknown.

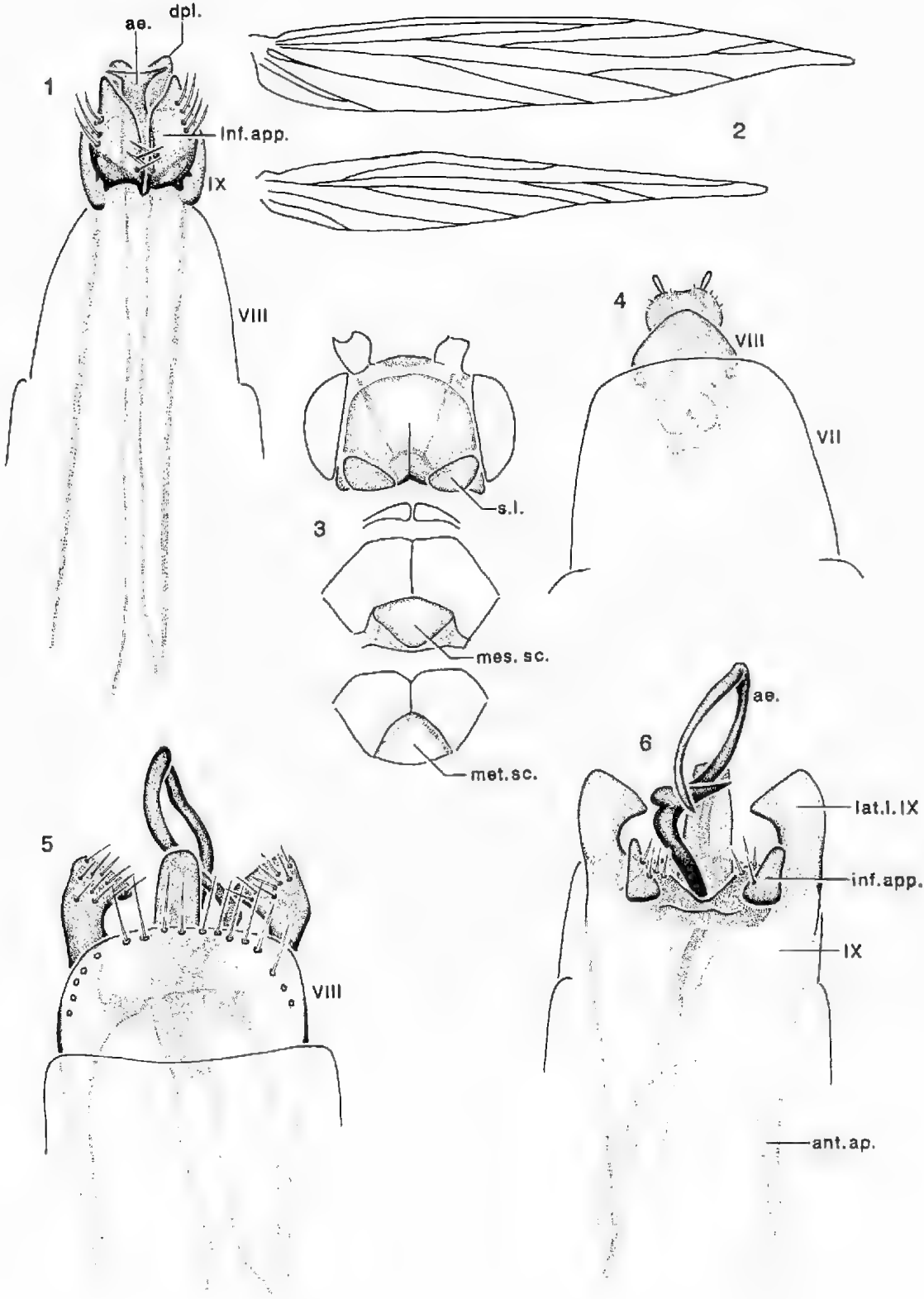
Distribution: Known only from the type locality and a macrophyte-rich settling pond, Alligator River's region, N.T.

Etymology: Named for P. Dostine who collected litres of other caddisflies.

Orphninoirichia Mosely

Orphninoirichia Mosely, 1934, p. 138; Mosely & Kimmins 1953, p. 510; Wells 1980, p. 628, 1985b, p. 644. Type species: *Orphninoirichia maculata* Mosely, by original designation.

Nine species in this endemic genus have been described previously. The type species, *Orphninoirichia maculata*, is widespread from south-central S.A., Tas., E Vic. to SE Qld. All others appear to be narrowly distributed although their



lack of attraction to light may have led to a false impression of their distributions. One species is recorded from Atherton Tableland in NE Qld (Wells 1980) but none from W.A. The new species is the first found west of the Great Dividing Range, and is probably part of a relictual Gondwanan fauna in the small, spring-fed stream at the base of the Kakadu Escarpment. No larvae have been collected, but as all others conform with that of *O. maculata* this new species is expected to be similar.

Orphnautrichia originis sp. nov.

FIGS 8-9

Holotype: NTM, ♂, N.T., Kakadu National Park, Radon Springs, 12°45'S, 132°55'E, 18-19.v.1988, Lt Tr., A. Wells & P. Suter.

Paratypes: NTM, ♀ (allotype), collected with holotype; NTM, NMV, 2 ♂♂, 4 ♀♀, same loc., 14.iv.89, Suter & Wells.

Diagnosis: Quite dissimilar to congeners; male distinguished by dorsal plate deeply cleft apically, females lack the ventral abdominal glands seen in other species.

Description: Adults. Uniformly dark grey, small. Male. Anterior wing length, 1.6 mm. Antennae 18-segmented, terminal segments pale, rest dark. Genitalia, Fig. 8. Segment IX produced postero-laterally to form lobes, each with a short inner ventral process; sternite deeply excavated. Dorsal plate membranous, deeply cleft apically. Subgenital plate tapered, apex rounded, sclerotised. Inferior appendages sub-triangular, bases separated widely by paired sclerotised processes, apices converging. Aedeagus of usual shape: elongate, slender, dilated towards rounded apex, trifurcator near base. Female. Anterior wing length, 1.5 mm. Antennae 17-segmented. Genitalia, Fig. 9. Segment VIII elongate, tapered distally. Terminal segments narrow, no prominent gland on abdominal sternite VII. Immatures unknown.

Distribution: Known from type locality only, Kakadu National Park, northern N.T.

Etymology: From the Latin -*originis* - source, in reference to the likely relictual nature of this and other components of the fauna of the type locality.

Hellyethira Neboiss

Hellyethira Neboiss, 1977, p. 42; Wells 1979b, p. 312; 1983, p. 632. Type species: *Xuthotrichia simplex* Mosely, by original designation.

Six new species are described, two from the Alligator Rivers region, three from Yuccabine Creek and one from northwestern W.A. Males of *H. radonensis* sp. nov., *H. forficata* sp. nov., and *H. naumanni* sp. nov. resemble members of the *eskensis* group, a distinct lineage amongst Australian *Hellyethira* (Wells 1979b), and *H. imparilobata* sp. nov. and possibly *H. quadrata* sp. nov. are in the *malleoforma* group. I am unable to place the highly irregular *H. spinosa* sp. nov. (here tentatively placed in *Hellyethira*), in any of the existing species groups. Its male genitalic parts are modified to form a set of complex and irregular spines and lobes. Three strongly asymmetric species occur in New Guinea (Wells in prep.), but all are distinct from *spinosa* sp. nov.; its immatures are unknown.

These six new species increase to 23 the number of Australian *Hellyethira*. In addition, four are known from New Guinea, one each from Sulawesi and Japan; one Australian species has been collected in New Caledonia.

Hellyethira forficata sp. nov.

FIGS 10, 45

Holotype: NTM, ♂, N.T., Kakadu National Park, Radon Springs, 12°45'S, 132°55'E, 18.v.1988, A. Wells & P. Suter.

Paratypes: NTM, 1 ♂, same loc. as holotype, 18-19.v.88, Wells & Suter; NTM, 4 ♂♂, Graveside Creek, 18.vii.88, P. Dostine.

Other material examined: N.T.: NTM, larvae, pupae, Radon Springs, 18.v.88, Suter & Wells; larvae and pupae, Koolpin Creek, 13°29'S, 132°35'E, 25.v.88, Suter & Wells, OSS voucher set.

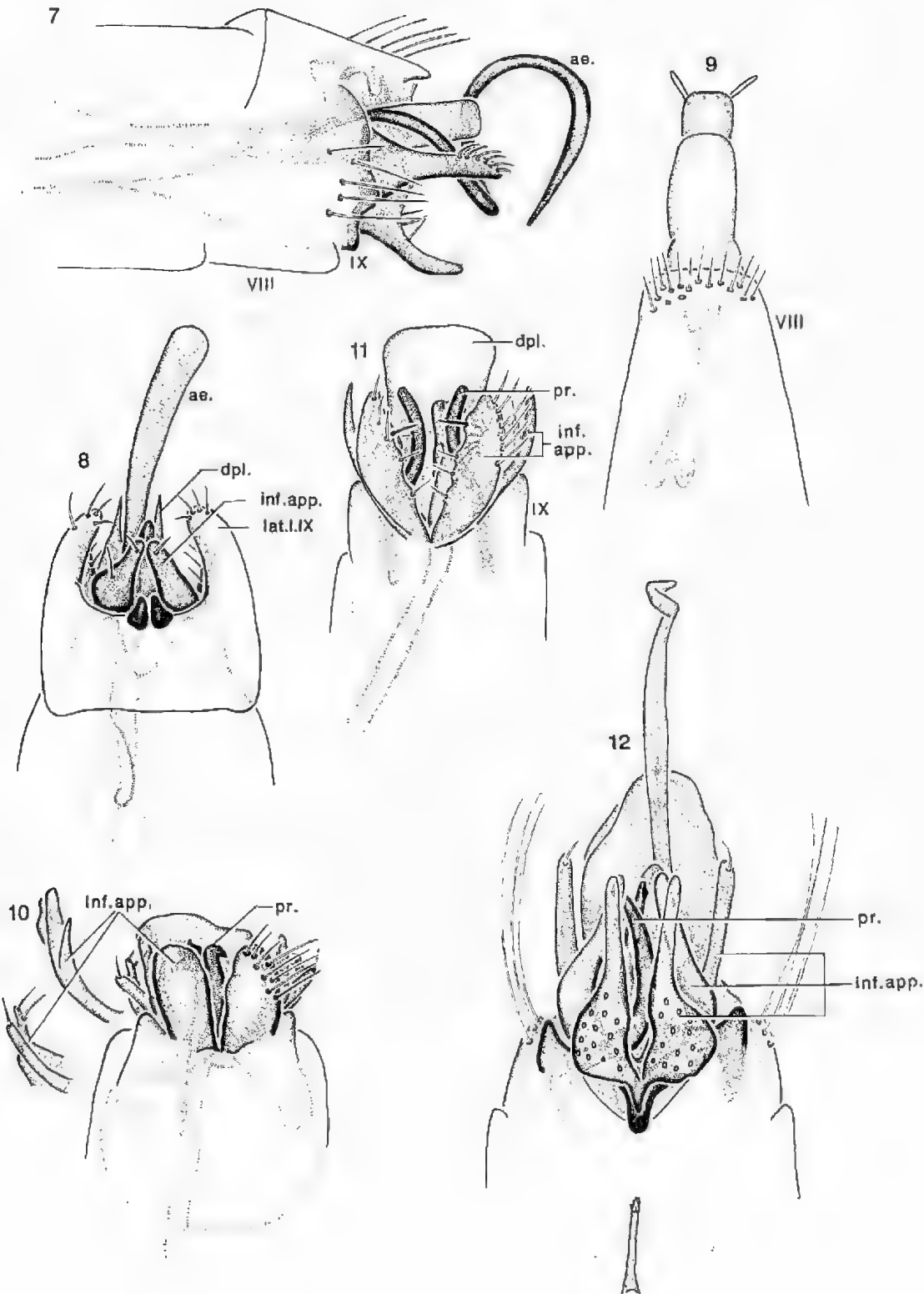
Diagnosis: In the *eskensis* group and most closely similar to *H. radonensis* sp. nov. Differing in parameres hooked sub-apically, apices acute; dorsal plate without spines or spinules.

Description: Male. Vestiture mottled, fawn-brown. Anterior wing length, 1.8 mm. Antennae 32-segmented. Genitalia, Fig. 10. A slender, apically-acute mesal process on sternite VII. Segment IX broadly rounded anteriorly in ventral view, postero-lateral margins produced in short triangular lobes, apical margin concave. Dorsal plate stout throughout length, membranous, without spines or spinules. Subgenital plate not seen. Inferior appendages with a broad, irregularly-

Fig. 1. *Chrysotrichia australis* sp. nov. 1, male genitalia, ventral view.

Figs 2-6. *Jabirichia dostinei* sp. nov. 2, male wings; 3, male, dorsal head and thorax; 4, female genitalia, ventral view; 5, 6, male genitalia, dorsal and ventral views.

Abbreviations: ae, aedeagus; ant. ap., anterior apodeme; dpl., dorsal plate; inf. app., inferior appendages; lat. 1. IX, lateral lobe of segment IX; mes. sc., mesoscutellum; met. sc., metascutellum; s.l., setal lobe; VII, abdominal segment VII; VIII, abdominal segment VIII; IX, abdominal segment IX.



shaped ventral lobe and four slender lobes posteriorly. Parameres scissor-like, hooked sub-apically, apices acute. Aedeagus slender, elongate, constricted slightly at about $\frac{2}{3}$ length. Female unknown. Mature larva pale. Case (Fig. 45) purse-shaped, valves constructed of fine sand with distinct dorsal and ventral margins, ends rounded, a shallow concavity dorsally in which a large sand grain is attached.

Distribution: Northern N.T., larvae collected from streams.

Etymology: From the Latin – *forficatus* – scissors-shaped, describing the parameres.

***Hellyethira radonensis* sp. nov.**

FIG. 11

Holotype: NTM, ♂, N.T., Kakadu National Park, Radon Springs, 12°45'S, 132°55'E, 18–19.v.1988, Lt Tr., A. Wells & P. Suter.

Paratypes: N.T.: NTM, 2 ♂♂, same loc., 14.iv.89, Suter & Wells; NMV, 1 ♂, same loc., 13–14.iv.89, Suter & Wells; NMV, 1 ♂, Magela Creek, at Ranger outlet pipe, 23.v.88, Wells & Suter; NTM, 1 ♂, Bower Bird Billabong at outlet, 12°47'S, 133°02'E, 1.x.88, Dostine.

Diagnosis: Closely resembling *H. veruta* (Wells 1985a) but males distinguished by the form of the base of the parameres which align with the body, rather than laterally; the digitiform, setate processes above the inferior appendages; and the additional upper lobe on inferior appendages with long setae on inner margin.

Description: Adults. Male. Anterior wing length, 1.9–2.0 mm. Antennae 33-segmented. Genitalia, Fig. 11. A slender, elongate mesal process on sternite VIII. Sternite IX roundly excavated apically. Dorsal plate broad throughout length, expanded distally, apical margin rounded, without spines or spinules. Subgenital plate not apparent. Inferior appendages multi-lobed: ventral lobe with outer margin broadly rounded, inner margin crenulate; dorsal lobe narrower, with a tuft of long setae sub-apically on inner margin; laterally a long, slender lobe without apical seta, and a shorter slender lobe with an apical seta. Parameres slender, loosely S-shaped, not overlapping, apices rounded. Aedeagus with a swollen membrane apically and twisted sclerotised process.

Female and immatures unknown.

Distribution: N.T., Kakadu National Park, Radon Springs and upper Magela Creek.

Etymology: Named for the type locality.

***Hellyethira naumanni* sp. nov.**

FIGS 12–13, 17

Holotype: NMV, ♂, W.A., Charnley River, 2 km SW Roly Hill, CALM Site 25/2, 16–20.vi.1988, I. D. Naumann.

Paratypes: NMV, 7 ♂♂, 1 ♀ (allotype), collected with holotype.

Diagnosis: An *eskensis*-group species differing from others in having all male genital parts slender and elongate distally; female resembles *H. vernoni* Wells.

Description: Male. Anterior wing length, 1.9–2.0 mm. Antennae 32-segmented. An elongate, slender mesal process on sternite VII. Segment IX short. Dorsal plate membranous, rounded distally. Subgenital plate sub-triangular, narrowly rounded apically. Inferior appendages in ventral view trilobed: ventral lobe broad-based, constricted mesally, narrow in distal half; above, two slender processes, the uppermost setate apically. In lateral view, these two dorsal processes can be seen as two lobes of a bifid branch. Parameres slender, overlying each other, inserted laterally. Aedeagus narrow, with an apical twist.

Female. Anterior wing length, 2.3 mm. Antennae 27-segmented. Sternite VIII with apical margin slightly notched medially, a pair of setae on each side of notch.

Immatures unknown.

Distribution: Collected from the type locality only.

Etymology: Named for I. D. Naumann who collected the specimens.

***Hellyethira imparalobata* sp. nov.**

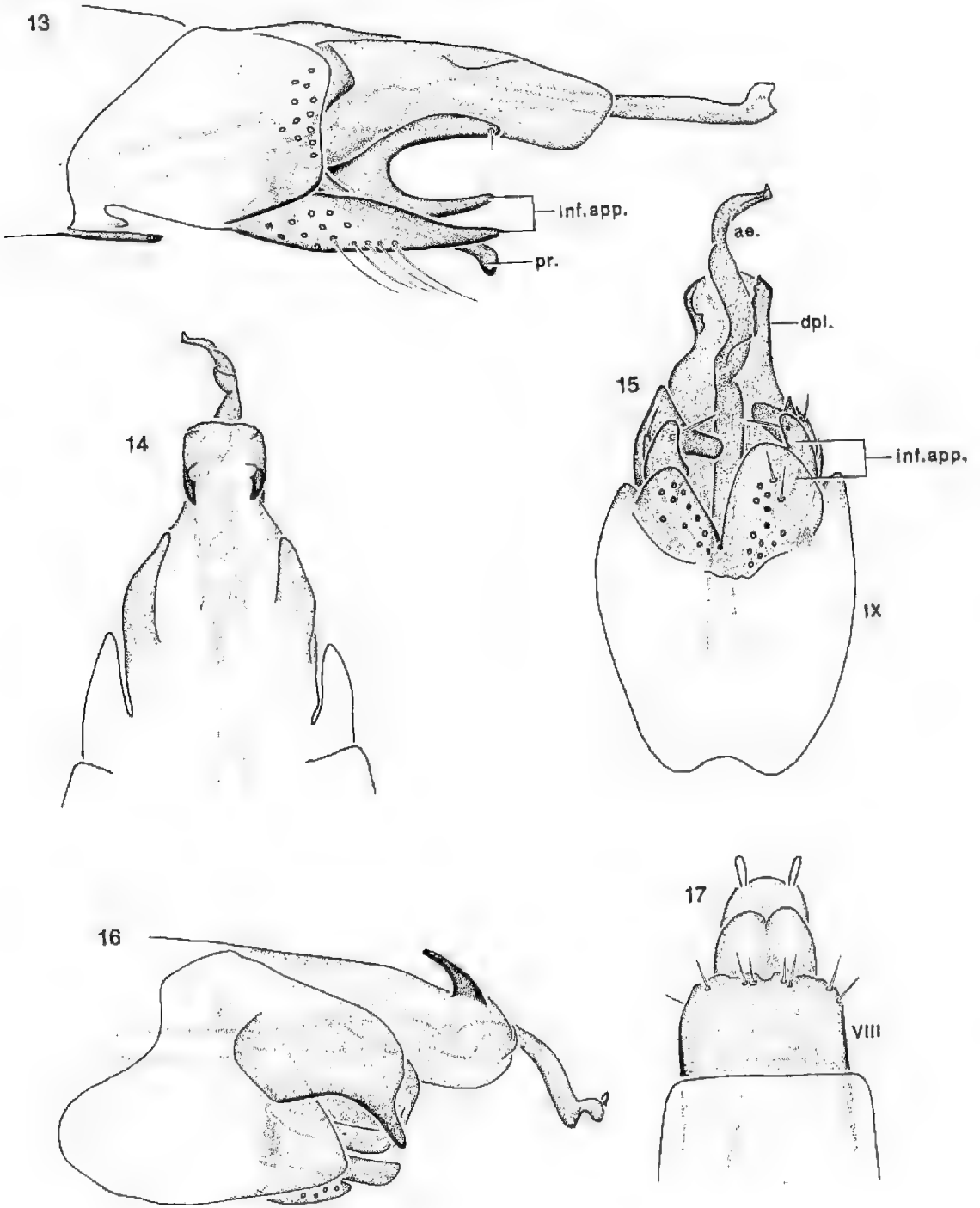
FIGS 14–16

Holotype: NMV, ♂, NE Qld, Yuccabine Creek, i.1985, R. G. Pearson & L. J. Benson.

Other material examined: NMV, 1 ♂, W.A., Charnley River, 2 km SW of Roly Hill, CALM site 25/2, 16°22'S, 125°12'E, 16–20.vi.88, I. D. Naumann.

Diagnosis: A close sister species to *H. vernoni* Wells, distinguished by asymmetrical inferior appendages and dorsal plate narrowly quadrate in distal half.

Figs 7–12. *Jabirichia dostinei* sp. nov. 7, male genitalia, lateral view. *Orphninostrichia originis* sp. nov. 8,9, male and female genitalia, ventral views. *Hellyethira forficata* sp. nov. 10, male genitalia, ventral view. *Hellyethira radonensis* sp. nov. 11, male genitalia, ventral view. *Hellyethira naumanni* sp. nov. 12, male genitalia, ventral view. Abbreviations: ae, aedeagus; dpl., dorsal plate; inf. app., inferior appendages; lar. l. IX, lateral lobe of segment IX; pr, paramere; VII, abdominal segment VIII; IX, abdominal segment IX.



Figs 13-17, *Hellyethira naumanni* sp. nov. 13, male genitalia, lateral view. *Hellyethira imparalobata* sp. nov. 14-16, male genitalia, dorsal, ventral and lateral views. *Hellyethira naumanni* sp. nov. 17, female genitalia, ventral view. Abbreviations: ae., aedeagus; dpl., dorsal plate; inf. app., inferior appendages; pr., paramere; VIII, abdominal segment VIII; IX, abdominal segment IX.

Description: Male. Anterior wing length, 1.8 mm. Antennae damaged. Genitalia, Figs 14–16. Abdominal sternite VII with slender, elongate mesal process. Dorsal plate broad-based, in distal half narrowly sub-quadrate with margins dark and paired sclerotised spines laterally. Subgenital plate not evident. Inferior appendages unequal, ventrally with a broad lobe, several narrower processes distally and paired styliform processes laterally. Broad, sclerotised structures laterally above inferior appendages may represent parameres. Aedeagus twisted in distal half.

Female and immatures unknown.

Distribution: Known from the type locality, northeastern Qld., and from Charnley River, northwestern W.A.

Etymology: From the Latin – *impar*, *lobatus* – unequal, lobed, in reference to the lobes of inferior appendages.

***Hellyethira quadrata* sp. nov.**
FIGS 18–19

Holotype: NMV, ♂, NE Qld., Yuccabine Creek, xii.1985, R. G. Pearson & L. J. Benson.

Paratypes: NMV, same loc. and collectors as holotype: 6 ♂♂, 5 ♀♀ (including allotype), ii.85; 12 ♂♂ v.85; 4 ♂♂, 5 ♀♀ ix.85.

Other material examined: NMV, same loc. and collectors: 11 ♂♂, x.84; 4 ♂♂, xi.84; 8 ♂♂, i.85; 1 ♂, vii.85; 4 ♂♂, ix.85; 1 ♂, xi.85; 1 ♂, i.86; 3 ♂♂, ii.86, 1 ♂, iv.86.

Diagnosis: Most closely resembling *H. ramosa* Wells, but male with inferior appendages wider than long, almost truncate distally, but with a pair of digitiform processes medially.

Description: Males. Anterior wing length, 2.0–2.2 mm. Antennae 31-segmented. Genitalia (Figs 18, 19). A slender, elongate mesal process on sternite VII. Segment IX sub-quadrate. Dorsal plate membranous, rounded distally. Subgenital plate not apparent. Inferior appendages (together as wide, in ventral view, as sternite IX, length about half width, inner apical margins produced posteriorly in a small lobe, a setate, digitiform process mesally. Aedeagus with several constrictions distally, hooked apically. Females and immatures unknown.

Distribution: From the type locality only, northeastern Qld.

Etymology: From the Latin – *quadrus* – square, for the general shape of male terminalia.

***Hellyethira spinosa* sp. nov.**
FIGS 20–22

Holotype: NMV, ♂, NE Qld., Yuccabine Creek; R. G. Pearson & L. J. Benson.

Paratypes: NMV, ♂, collected with holotype.

A curious species, originally believed to represent a new genus (Benson & Pearson 1988 – “unidentified genus A”), but here referred to *Hellyethira* with which it conforms in general respects, although the aedeagus more closely resembles those of the new species in *Acritoptila*. **Diagnosis:** Males readily recognised by the array of digitiform processes and irregular spines which replace the more usual genitalic structures; affinities obscure.

Description: Male. Anterior wing length, 1.6–1.8 mm. Antennae 28-segmented. Genitalia, Figs 20–22. Abdominal sternite VII with slender, elongate mesal process. Dorsal plate membranous, rounded apically. Subgenital plate probably represented by the two setate, digitiform processes, fused basally (Fig. 22b). The homologues of a second pair of similar processes (Fig. 22c) are unknown. Inferior appendages (Fig. 22d) broad-based, constricted medially, finger-like distally, with paired apical setae. Parameres forming a set of irregular spines (Fig. 22a). Aedeagus slender, elongate, hooked apically.

Female and immatures unknown.

Distribution: Known only from the type locality, Yuccabine Creek, northeastern Qld.

Etymology: From the Latin – *spina* – thorn, describing the spiny form of the male genitalia.

***Acritoptila* Wells**

Acritoptila Wells, 1982, p. 262; Kelley 1989, p. 190. Type species: *Acritoptila globosa* Wells, by original designation.

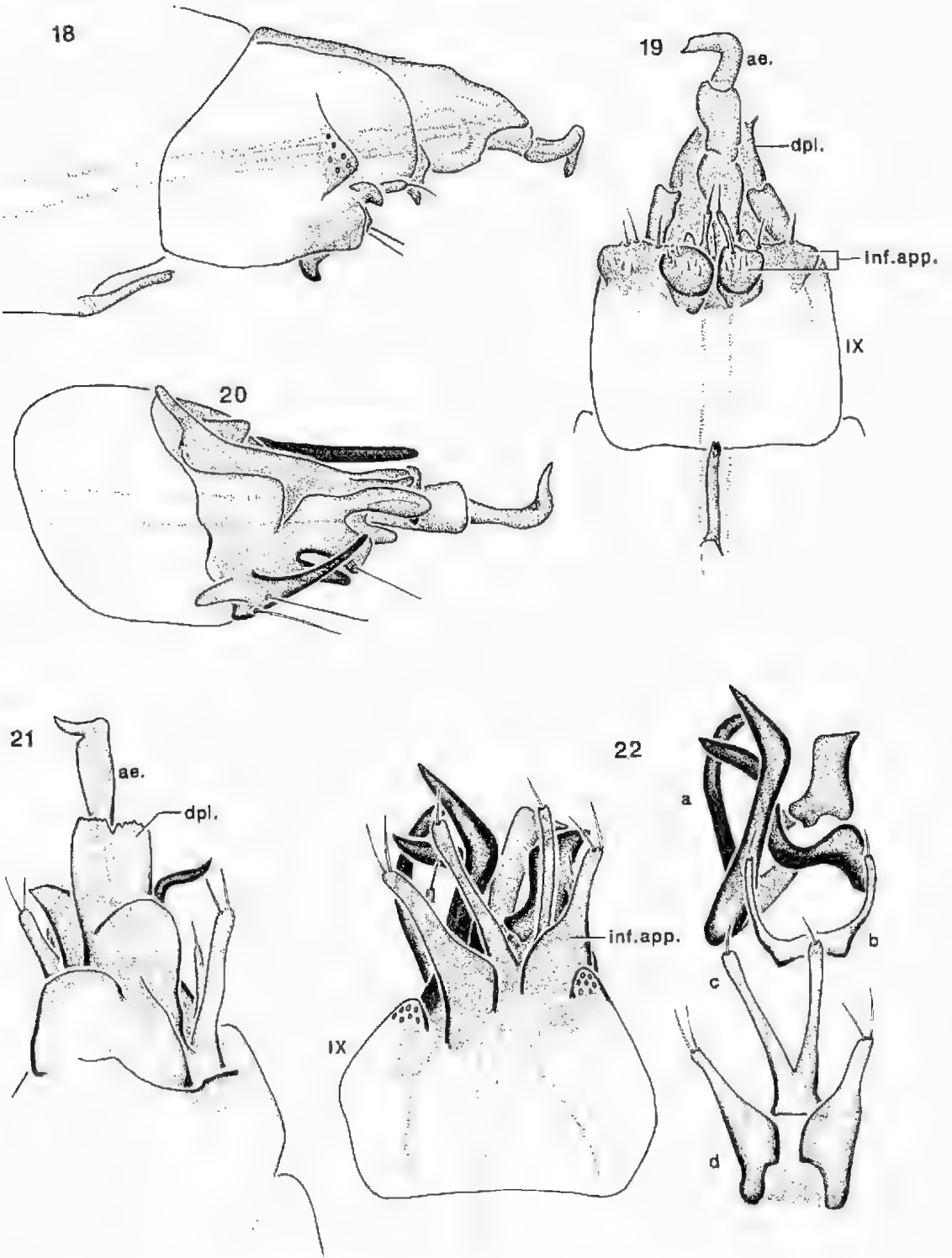
A small genus closely resembling *Hellyethira* in general body features, but with male genitalic structures simpler and tending to be fused. Larvae known for Western Australian species are distinguished from *Hellyethira* by the less pronounced constriction of the first two abdominal segments (Wells 1985b). Two new species from Yuccabine Creek (originally identified as *Hellyethira* sp. C and D for Benson & Pearson 1988) raise Australian representation to five; six are known from New Caledonia (Kelley 1989).

***Acritoptila pearsoni* sp. nov.**
FIGS 23–24

Holotype: NMV, ♂, NE Qld., Yuccabine Creek, iii.1986, R. G. Pearson & L. J. Benson.

Paratypes: NMV, 1 ♂, collected with holotype; NMV, 1 ♂, same loc. and collectors, ii.85.

Diagnosis: Resembling *A. humata* Wells in the elongate postero-lateral processes on abdominal segment IX and paired spines on lateral margins of dorsal plate, but with distinctive ventral genitalic processes.



Figs 18-22. *Hellyethira quadrata* sp. nov. 18,19, male genitalia, lateral and ventral views. *Hellyethira spinosa* sp. nov. 20-22, male genitalia, lateral, dorsal and ventral views. Abbreviations: a, b, c, d, displaced genitalic structures; ae., aedeagus; dpl., dorsal plate; inf. app., inferior appendages; IX, abdominal segment IX.

Description: Male. Anterior wing length, 1.7–1.9 mm. Antennae 37-segmented. Genitalia, Figs 23, 24. Abdominal sternite VIII with a slender, elongate mesal process. Segment IX with setose postero-lateral lobes. Dorsal plate membranous, rounded apically, overlaid by a short, triangular, sclerotised lobe antero-mesally, and bordered by irregular stout, dark spines inflected at right-angles sub-apically. Inferior appendages fused, with a small Y-shaped process apico-mesally, and stout, divergent lobes laterally, each tipped with a hair. A small process dorsal to inferior appendages may represent the subgenital plate. Aedeagus slender mesally, expanded distally, a long, sclerotised spur apically. Female and immatures unknown.

Distribution: Known only from the type locality, northeastern Qld.

Etymology: Named for R. C. Pearson who collected much of the material used in this study.

Aeritoptila capistra sp. nov.
FIGS 25–26

Holotype: NMV, ♂, NE Qld, Yuccabine Creek, xi. 1984, R. G. Pearson & L. J. Benson.

Paratypes: NMV, same loc. and collectors: 1 ♂, collected with holotype; 1 ♂, i.85; 1 male, ii.85; 1 male, iii.86; 1 ♂, v. 86.

Diagnosis: Males recognised by the broad, strap-like spines wrapping around the dorsal plate.

Description: Male. Anterior wing length, 1.9–2.2 mm. Antennae 31-segmented. Genitalia, Figs 25, 26. Abdominal sternite VII with a slender, elongate mesal process. Segment IX not produced postero-laterally, although dorso-lateral spines are present, twisting sharply and wrapping around the dorsal plate. Dorsal plate membranous, constricted in basal half, expanded distally, then tapered towards apex. No subgenital plate evident. Inferior appendages fused at bases, forming stout lobes distally. Aedeagus elongate, slender throughout length, slightly hooked sub-apically, apex acute. Females and immatures unknown.

Distribution: Known only from the type locality, northeastern Qld.

Etymology: From the Latin – *capistrum* – halter, to describe the twisting strap-like spines wrapping about the dorsal plate.

Oxyethira Eaton

Oxyethira Eaton, 1873, p. 143; Kelley 1984, p. 435. Type species: *Hydroptila costalis* Curtis *sensu* Eaton, by original designation.

Trichoglene Neboiss, 1977, p. 43. Type species: *Trichoglene columba* Neboiss, by original designation.

Previously, only two of the 10 subgenera comprising *Oxyethira* (Kelley 1984) were recorded from Australia: the most primitive sub-genus, *O. (Trichoglene)* Neboiss, from the south and east, and a more highly derived group, *O. (Dampfitrichia)* Mosely, from the north. Now a third, *O. (Oxyethira)* Eaton, is added, with the discovery of the Oriental *O. (Oxyethira)* *bogambara* in the north-east.

Of particular interest is the new species *O. (Trichoglene)* *cornutata* sp. nov. from the Alligator Rivers region, again from the small monsoon forest stream, Radon Springs. Its closest associations are with a New Caledonian species, tending to support the thesis that this stream harbours components of a relictual fauna.

Originally, I considered that the third species reported here, *O. complicata* sp. nov., represented another new genus (Benson & Pearson 1988, 'unidentified genus sp. A.'). More cautiously, it is now placed in *Oxyethira* with which it shares general features such as shape of wings and venation, antennal form, ocelli 3 and in males titillator present on aedeagus and anterior margin of abdominal segment IX rounded. But it has a tibial spur formula of 0,2,4, which occurs only in members of the *minima* group in *O. (Dampfitrichia)* and, in the male, abdominal segment IX not retracted in VIII and genitalic structures highly asymmetric. It is not assigned to any sub-genus. I am unaware of any other *Oxyethira* species with highly asymmetrical genitalia – a state which is usually considered to be derived.

Oxyethira (Oxyethira) bogambara Schmid

Oxyethira bogambara Schmid, 1958, p. 67.

Holotype: male, Ceylon, Kandapola, USNM.

New Records: NMV: 1 ♂, NE Qld, Yuccabine Creek, x.84, Benson & Pearson; 1 ♂, same loc., 10.iv.85; 2 ♂♂, 2 ♀♀, same loc., v.85; 1 ♂, same loc., i.86; 1 ♂, same loc., i.86.

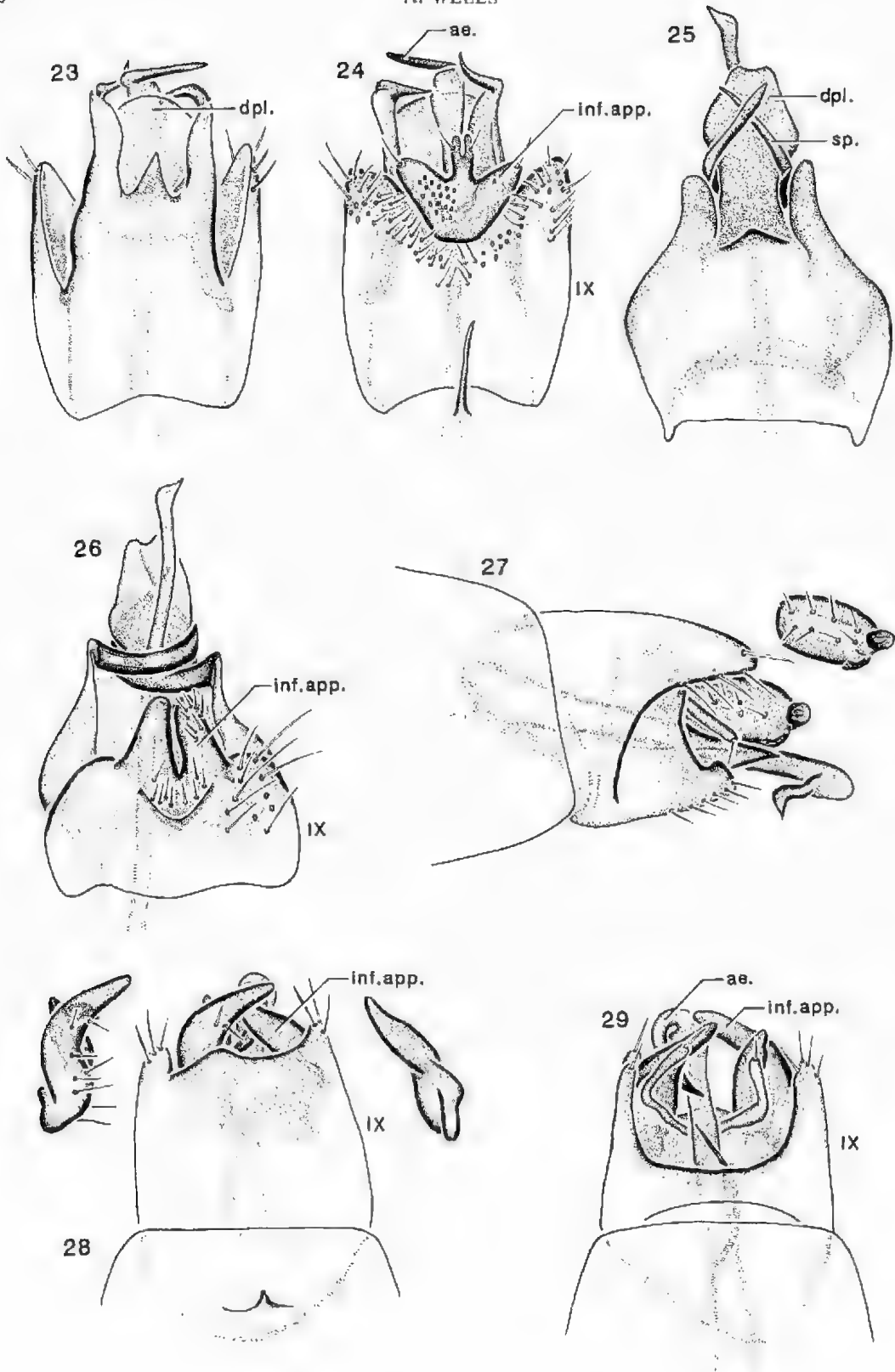
In the Oriental *ramosa* group, *O. (Oxyethira)* (Kelley 1984), and, like *Oxyethira incana* Ulmer, probably a species that has dispersed recently to Australia via New Guinea.

Males readily recognised by the titillator twisted 2 to 3 times around the aedeagus (Schmid 1958). Females by the stout terminalia and V-shaped structure on sternite VIII (Wells & Dudgeon 1990).

Distribution: S.E. Asia, New Guinea, northern Aust.

Oxyethira complicata sp. nov.
FIGS 27–29

Originally designated "New genus sp. B" for Benson & Pearson (1988) this unusual species is now placed tentatively in *Oxyethira*, but left in *incertae*



sedis, as it cannot be assigned to any of the existing sub-genera.

Holotype: NMV, ♂, NE Qld. Yuccabine Creek, 11.1986, R. G. Pearson & L. J. Benson.

Paratypes: NMV, same loc. and collectors as holotype: 2 ♂♂, collected with holotype, 1 ♂, xii.85; 1 ♂, iv.86.

Diagnosis: Males recognised by the combination of presence of ocelli, spur formula 0,2,4, and highly asymmetric genitalic appendages.

Description: Male. Anterior wing length, 1.7–1.8 mm. Antennae 27-segmented, flagellar segments with abundant *sensilla auricillica*. Genitalia, Figs 27–29. Abdominal segment VII with a small acute spur apico-mesally. Segment IX well protruded from VIII, anterior margin broadly rounded, postero-lateral lobes rounded distally; sternite with apical margin deeply excavated. Subgenital plate not evident. Inferior appendages asymmetrical, sclerotised, complexly multilobed, with paired, irregularly-twisted, setate, digitiform processes dorsally; Aedeagus straight, with a slender titillator, and strongly recurved apical spine.

Female and immatures unknown.

Distribution: Known only from the type locality, northeastern Qld.

Etymology: From the Latin – *complicatus* – complicated, for the genitalic structures that defy interpretation.

Oxyethira (Trichoglene) cornutata sp. nov.

FIGS 30–31

Holotype: NTM, ♂, N.T., Kakadu National Park, Radon Springs, 12°45'S, 132°55'E, 14.iv.1989, A. Wells & P. Suter.

Diagnosis: Referred to *O. (Trichoglene)* and most closely resembling the New Caledonian *O. insularis* Kelley (1989) with which it shares the form of the inferior appendages, but also showing some resemblance to *O. brevis* Wells from SW W. Aust., and *O. caledonensis* Kelley from New Caledonia.

Description: Male. Uniformly dark grey. Anterior wing length, 1.3 mm. Antennae 26-segmented, with alternating bands of light and dark segments. Genitalia, Figs 30, 31. Abdominal segment IX narrow, elongate, anterior margin rounded, reaching into segment VII. Dorsal plate short, rounded, with a sclerotised process on each side. Subgenital plate membranous, divided into two lobes by rounded median excision. Bilobed process slightly longer

than other genitalic parts. Inferior appendages forming a pair of widely divergent arms. Aedeagus broadly hooked apically.

Female and immatures unknown.

Distribution: Known only from one male from a small monsoon forest stream, Kakadu National Park, N.T.

Etymology: From the Latin – *cornulus* – horn-like, describing the form of the inferior appendages.

Orthotrichia Eaton

Orthotrichia Eaton, 1873, p. 141. Type species: *Hydropitila angustella* McLachlan, by original designation.

Eight new species referred to *Orthotrichia* raise to 43 the Australian representation. Four are in the *gracilis* group (Wells 1979c), three in the more diverse *adornata/kokodana* group (Wells 1984), and one in the *aberrans* group. Additional records of established species extend their distributions, and cases of several of these are figured.

Orthotrichia amica sp. nov.

FIGS 32–33, 47

Holotype: NTM, ♂, N.T., Kambolgie Creek, 13°32'S, 132°23'E, 25.v.1988, I.A. Tr., A. Wells & P. Suter.

Paratypes: NTM, NMV, 6 ♂♂, same loc. as holotype, 25.v.88, UV Lt, Suter & Wells.

Other material examined: NTM, pupae, same loc. as holotype, 25.v.88, Wells; NTM, ♂ pupa and cases, N.T., South Alligator River at Gimbat OSS Station, 13°35'S, 132°36'E, Wells.

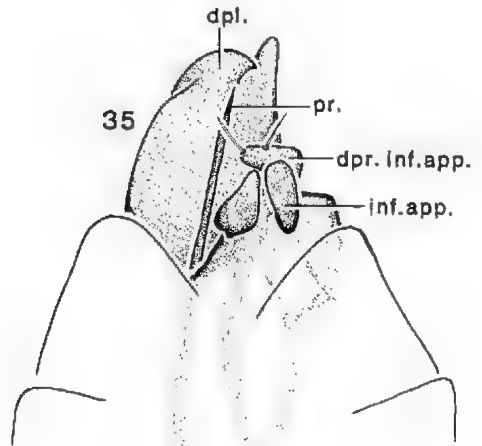
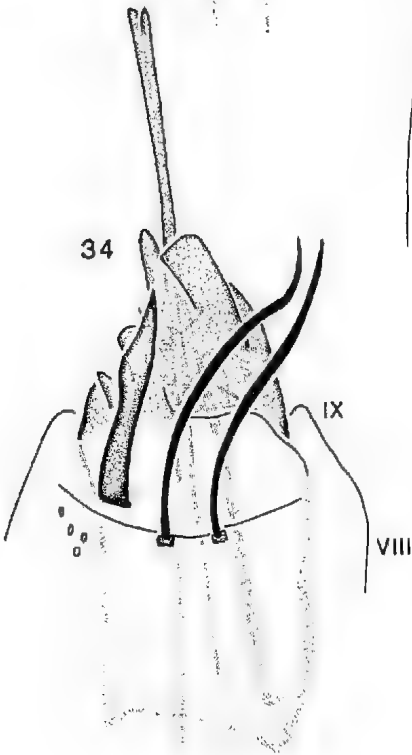
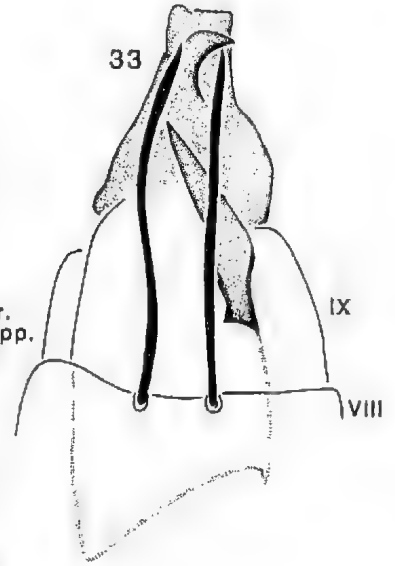
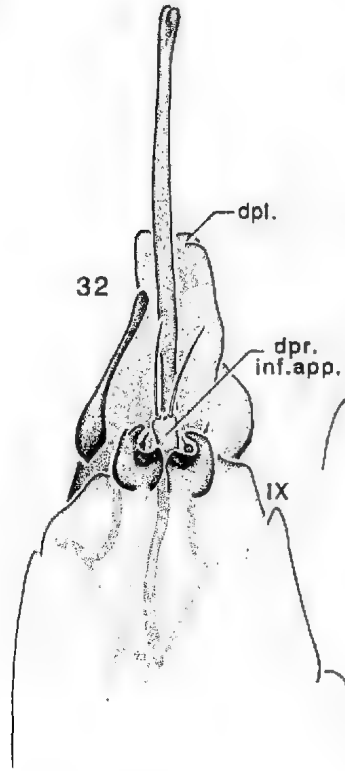
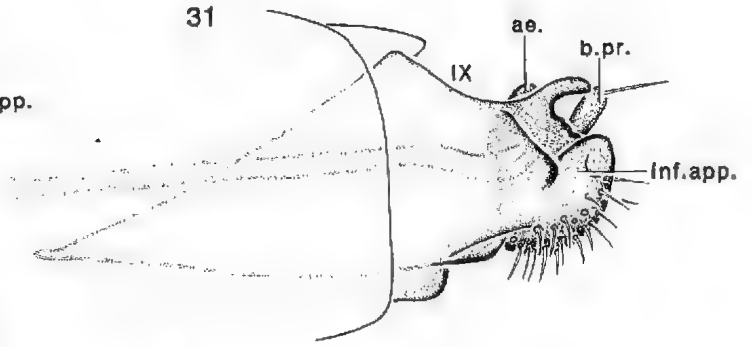
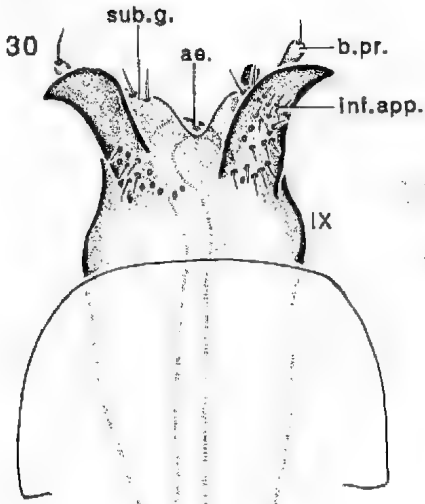
Diagnosis: In the *gracilis* group and closely resembling *O. kholoensis* Wells and *O. paranga* Wells from which it differs in shape of inferior appendages and presence of a small, pale spur distally on dorsal plate.

Description: Male. Anterior wing length, 1.7 mm. Antennae 26-segmented. Genitalia, Figs 32, 33. Tergite VIII with a pair of strong, black, spiny setae on apico-mesal margin. Tergite IX with left lateral spine broad, blade-like. Dorsal plate elongate, membranous except for left ventral margin; a small laterally-directed spur distally; apex truncate, about one third width of base. Inferior appendages in ventral view with a concavity apico-mesally; dorsal process slender, undivided.

Female unknown.

Figs 23–29, *Acritoptila pearsoni* sp. nov. 23,24, male genitalia, dorsal and ventral views. *Acritoptila capistra* sp. nov. 25,26, male genitalia, dorsal and ventral views. *Oxyethira complicata* sp. nov. 27–29, male genitalia, lateral, ventral and dorsal views.

Abbreviations: ae., aedeagus; dpl., dorsal plate; inf. app., inferior appendages; sp., spine; IX, abdominal segment IX.



Pupal case (Fig. 47). Of characteristic form, dark with short ribs dorsally.

Distribution: Collected from the upper reaches of the South Alligator River, and one of its small tributaries, N.T.

Etymology: From the Latin – *umnicus* – of a stream, pertaining to type locality, a small stream.

***Orthotrichia fontinalis* sp. nov.**

FIGS 34–35

Holotype: NTM, ♂, N.T., Kakadu National Park, Radon Springs, 12°45'S, 132°55'E, 18–19.v.1988, Lt Tr., P. Suter & A. Wells.

Paratypes: NTM, NMV, 10 ♂♂, collected with holotype; NMV, 1 ♂, same loc., 13–14.iv.89, Wells & Suter; NTM, 1 ♂, N.T., Kakadu National Park, Bowerbird Billabong, 12°47'S, 133°02'E, 1.x.88, Dostine.

Diagnosis: Another *gracilis* group member, with male genitalia similar to *O. attenuata* Wells but distinguished by asymmetry of inferior appendages and their dorsal process.

Description: Male. Anterior wing length, 1.2 mm. Antennae 24-segmented. Genitalia, Figs 34, 35. Paired, black, spiny setae apicomeresally on tergite VIII. Right dorsal spine only on tergite IX. Dorsal plate irregularly bilobed distally, left lobe slightly hooked apically. Paramere elongate, slender. Inferior appendages asymmetrical; in ventral view, separated basally, converging distally, left subtriangular, right almost ovoid; dorsal process undivided, arising on right, curving to left. Female and immatures unknown.

Distribution: Known only from two localities in Kakadu National Park, N.T.

Etymology: From the Latin – *fontinalis* – of a spring, pertaining to the collecting site.

***Orthotrichia tomentosa* sp. nov.**

FIGS 36–37

Holotype: NTM, ♂, N.T., Kakadu National Park, Radon Springs, 12°45'S, 132°55'E, Lt Tr., 18–19.iv.1988, P. Suter & A. Wells.

Paratypes: N.T.: NTM, NMV, 6 ♂♂, collected with holotype; 1 ♂, Gulgungul Creek at inlet to Gulgungul Billabong, 20.iv.89, Wells & Suter.

Diagnosis: In the *gracilis* group, with males closely resembling *O. aculeata* in form of inferior appendages and their dorsal process but distinguished by the dark, curved spine to the left of the dorsal plate.

Description: Anterior wing length, 1.5 mm. Antennae damaged. Genitalia (Figs 36, 37). A pair of stout black, spinose setae offset from posterior margin of tergite VIII. Abdominal segment IX with obliquely truncate anterior margin, a strongly curved, dark spine arising apically on left and pressing against dorsal plate. Dorsal plate narrowly rounded apically. Inferior appendages ovoid, setose, separated at bases, converging apically; process of inferior appendages short, undivided, lying on right. Paramere slender, elongate. Female and immatures unknown.

Distribution: Collected from two sites in Kakadu National Park, N.T.

Etymology: From the Latin – *tomentum* – hairy, describing the appearance of the inferior appendages.

***Orthotrichia serrata* sp. nov.**

FIGS 39–40

Holotype: NTM, ♂, N.T., Kakadu National Park, Radon Springs, 12°45'S, 132°55'E, Lt Tr., 18–19.v.1988, P. Suter & A. Wells.

Paratype: NTM, 1 ♂, same data as holotype.

Diagnosis: A *gracilis* group member, with close similarities to *O. paranga*, but differing in the shape of inferior appendages and their process, and the irregular-shaped sclerotised spine along left of dorsal plate.

Description: Male. Anterior wing length, 1.5 mm. Antennae damaged. Genitalia, Figs 39, 40. Paired black spiny setae subapical on tergite VIII. Right lateral spine on segment IX blade-like, left irregular in shape, broad in proximal 2/3, slender distally, apex slightly expanded. Dorsal plate about same width throughout length. Inferior appendages discrete, inner margins dark, toothed; dorsal process asymmetric, slender, arising on right, arching towards left. Paramere slender, elongate. Female and immatures unknown.

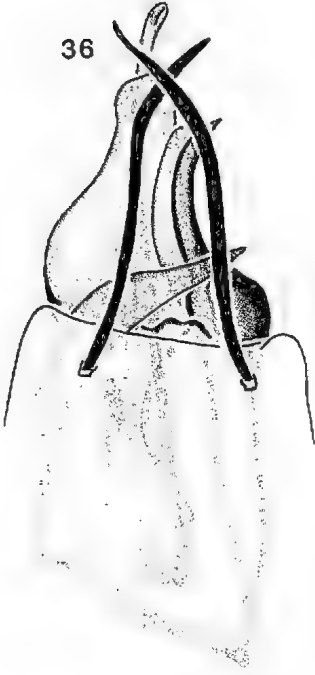
Distribution: Known only from the type locality, Kakadu National Park, N.T.

Etymology: From the Latin – *serratus* – notched, to describe the inner margin of inferior appendages.

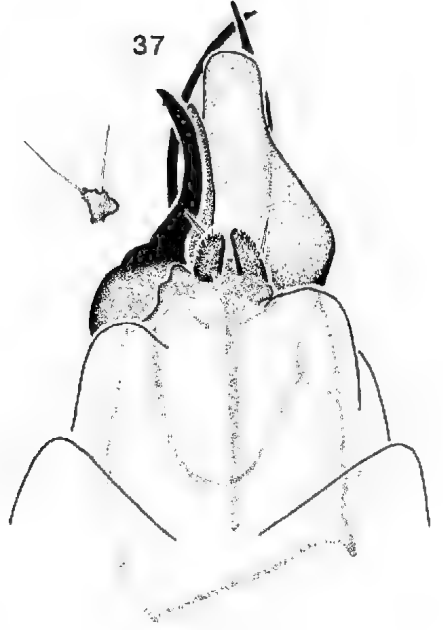
Figs 30–35. *Oxyethira cornutata* sp. nov. 30, 31, male genitalia, ventral and lateral views. *Orthotrichia amica* sp. nov. 32, 33, male genitalia, ventral and dorsal views. *Orthotrichia fontinalis* sp. nov. 34, 35, male genitalia, dorsal and ventral views.

Abbreviations: ac., aedeagus; b.pr., bilobed process; dpr. inf. app., dorsal process of inferior appendages; dpl., dorsal plate; inf. app., inferior appendages; pr., paramere; sub.g., subgenital plate; VIII, abdominal segment VIII; IX, abdominal segment IX.

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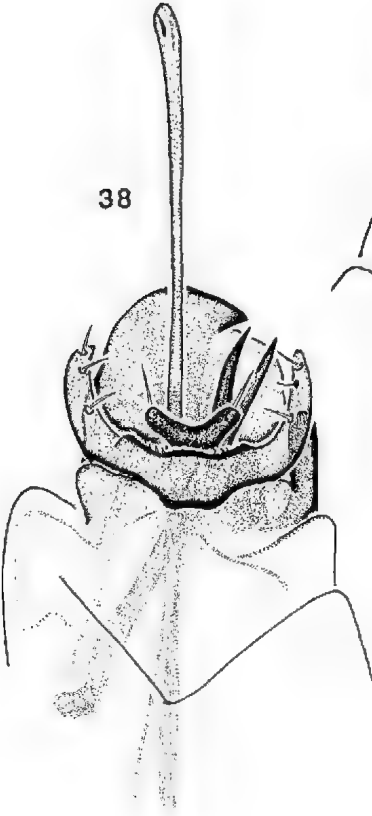
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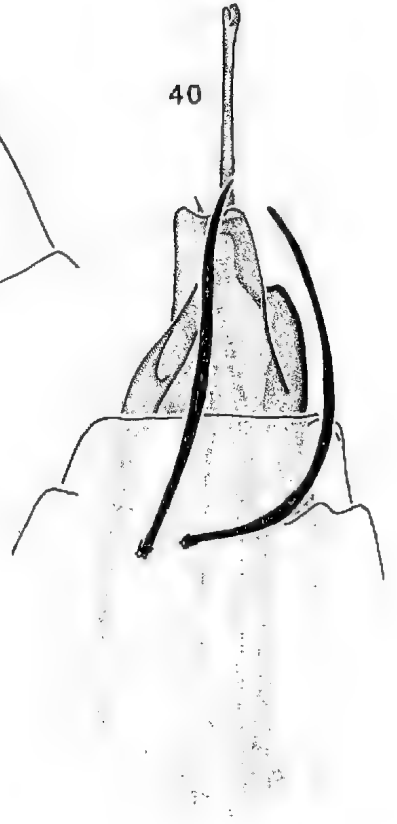
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Orthotrichia paranga Wells
FIG. 46

Orthotrichia paranga Wells, 1979c, p. 614.

Holotype: ♂, W.A., Ord River Dam, 21.ii.1977, WAM.

New records: N.T.: NTM, 1 ♂, Magela Creek at Rum Pipe, 17.ii.88, Dostine; NTM, 1 ♂, Kambolgie Creek, 13°32'S, 132°23'E, Lt Tr., 25–26.v.88, Wells & Suter; 1 ♂ pupa and case, Fisher Creek above South Alligator River junction, 13°34'S, 132°34'E, Wells & Suter, OSS voucher set.

Originally described from NW W.Aust., *O. paranga* closely resembles *O. stipa* Wells, *O. kholoensis* Wells and *O. fontinalis*, but differs in shape of inferior appendages and their dorsal process. The pupa has been associated.

Pupal case (Fig. 46). Length, 2.2 mm. Darkly pigmented, dorso-ventrally flattened, with finely serrate ribs extending full length.

Distribution: Eastern Qld, northern N.T.

Orthotrichia tyleri Wells
FIGS 51–52

Orthotrichia tyleri Wells, 1979c, p. 617.

Holotype: ♂, W. Aust., Mitchell Plateau, Camp Creek, 20.vii.1978, WAM.

New records: Cased pupae, N.T., Yellowwaters Billabong, 21.v.88, Dostine, OSS voucher set.

Males are distinguished by widely separated, strong, black, spiny setae on abdominal tergite VIII; a *gracilis* group member.

Pupal case (Figs 51, 52). Length, 2.4 mm. Pale, transparent; long, slender, tapering at each end, without ribs, a pair of vents opening on the dorsal margin as in *O. turrita* Wells (Wells 1985b).

Distribution: Northwestern W.A., northern N.T. This is a common species in lentic and lotic systems; immatures collected from stems of an aquatic macrophyte, *Hydrilla* sp.

Orthotrichia furcata sp. nov.
FIG. 38

Holotype: NTM, ♂, N.T., South Alligator River above Fisher Creek junction, Lt Tr., 19–20.iv.1989, P. Suter & A. Wells.

Paratype: NTM, 1 ♂, N.T., Kakadu National Park, Magela Creek at outlet to Bowerbird Billabong, 1.x.88, Dostine.

Diagnosis: An *adornata* group species with elongate inferior appendages fused medially, and paramere bifid apically.

Description: Male. Anterior wing length, 2.1–2.3 mm. Antennae 27-segmented. Genitalia, Fig. 38. Abdominal sternite VIII with brush of blunt, black setae mesally. Segment IX short. Dorsal plate broad, rounded apically, a small spur on margin. Inferior appendages elongate, widely separated distally, bases fused; dorsal process Y-shaped. Paramere stout, dark, distally bifid, apices acute. Female and immatures unknown.

Distribution: Known only from two localities, Kakadu National Park, N.T.

Etymology: From the Latin –*furcatus* – forked, to describe the forked paramere.

Orthotrichia alata sp. nov.
FIGS 41–42, 48–49

Holotype: NTM, ♂, N.T., Kambolgie Creek, 13°32'S, 132°23'E, Lt Tr., 25–26.v.1988, A. Wells & P. Suter.

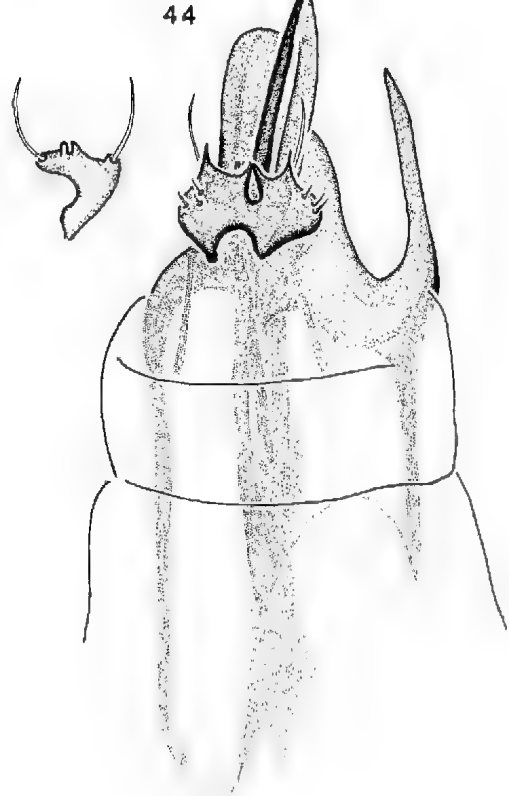
Paratypes: NTM, 2 ♂♂, N.T., Kakadu National Park, Radon Springs, 12°45'S, 132°55'E, 18–19.v.88, Suter & Wells; NMV, 5 ♂♂, same loc., 13–14.iv.89, Suter & Wells; NTM, 1 ♂, South Alligator River, Gimbat Station, 26.iv.88, Dostine; NTM, 10 ♂♂, Graveside Creek, 18.vii.88, Dostine; NMV, 1 ♂, Creek 5 km W of OSS Gimbat station, 19.iv.89, Wells & Suter.

Other material examined: NTM, NMV, larvae, pupae, cases, N.T., Kakadu National Park, Baroalba Springs, 12°49'S, 132°52'E 22.v.88, Wells & Suter; NTM, immatures, South Alligator River, numerous records, Dostine.

Diagnosis: In the *adornata* group; males with irregular and strongly asymmetric inferior appendages resembling those of *O. tyleri* Wells; cases recognised by distinctive lateral flanges.

Description: Male. Anterior wing length, 1.7 mm. Antennae 25-segmented. Genitalia, Figs 41, 42. Tergite VIII without black setae. Sternite IX rounded anteriorly; tergite with right lateral spine only, stout, curving towards left distally. Dorsal plate irregularly rounded apically, a deep notch in right lateral margin, sclerotised spur subapically. Inferior appendages comprised of irregular lobes, sclerotised distally; dorsal process small, slightly divided subapically, lobes divergent.

Female unknown.



Larval and pupal cases (Figs 48, 49). Length of pupal case, 1.8–2.1 mm. Black, without usual dorsal ribs but with lateral margins expanded and raised to form "wings" or flanges, a furrow mid-dorsally. *Distribution*: Alligator Rivers region, N.T., where it occurs in small streams on the edge of the escarpment and in the higher reaches of the South Alligator River.

Etymology: The Latin - *alatus* - furnished with wings, describing the flanges on the cases.

Orthotrichia scutata Wells

FIG. 55

Orthotrichia scutata Wells, 1979c, p. 599.

Holotype: ♂, W. Aust., Spillway Creek, Ord River Dam, 20.ii.1977, WAM.

New Records, N.T.: NTM, 1 ♂, South Alligator River at Gimbat OSS Station, 13°35'S, 132°36'E. 28.iv.88, Dostine; NTM, larvae, pupae, same loc., 24.v.88, Wells & Suter.

In samples of congeners, *O. scutata* can be recognised by its large size and dark colour; males have right lateral spine on abdominal tergite IX broadly bilobed and visible in ventral view as a "bract" about the left margin of the dorsal plate. *Larval and pupal cases*. Pupal case length, 2.3–2.7 mm. Case (Fig. 55) dark brown, larger than other *Orthotrichia* except *uberrans* group members, relatively stout, with short ribs dorso-mesally, pupal case with posterior end longer than anterior end. *Distribution*: Northwestern W.A., northern N.T. Immatures collected from undersides of rocks in flowing water.

Orthotrichia bensoni sp. nov.

FIG. 44

Holotype: NMV, ♂, NE Qld, Yuccabine Creek, xi.1984, L. J. Benson & R. G. Pearson.

Paratypes: NMV, 3 ♂♂, same loc. and collectors, ii.85.

Diagnosis: In the *adornata* group, and distinguished by the slender lateral spine projecting posteriorly on the right side, well away from other genitalic structures.

Description: Male. Anterior wing length, 1.4–1.6 mm. Antennae 22-segmented. Genitalia, Fig. 44. Abdominal segment IX rounded distally, with a strong, dark, slender right lateral spine. Dorsal plate in form of two stout spines, one 2x length of other, each with apex curving inwards. Inferior appendages rounded laterally, fused basally, divided distally, with slender tapered projections apico-laterally; dorsal process asymmetrical, arching from

right to left, left arm produced and notched. Paramere elongate.

Female and immatures unknown.

Distribution: Northeastern Qld, Yuccabine Creek.

Etymology: Named for one of the collectors, L. J. Benson.

Orthotrichia suteri Wells

FIGS 54, 56

Orthotrichia suteri Wells, 1979c, p. 605.

Holotype: ♂, W. Aust., Mitchell Plateau, Camp Creek, 3.vii.1978, WAM.

New Records, N.T.: NTM: Jabiru, Ranger Retention Pond 1, 16.iv.89, A. Wells.

A tiny caddisfly described from northwestern W.A., male recognised by long, widely divergent lobes on the dorsal process of inferior appendages.

Larval and pupal cases (Figs 54, 56). Small slender, transparent, without ribs, larval case tubular, pupal case bluntly rounded anteriorly, tapered posteriorly.

Distribution: Northwestern W.A., northern N.T. Collected from beneath *Nymphæa* and *Nymphoides* leaves in still water.

Orthotrichia velata Wells

FIG. 50

Orthotrichia velata Wells 1983, p. 641.

Holotype: ♂, Qld, Upper Ross River, below weir, 8.v.1979, NMV.

New Records, N.T.: NTM: 1 ♂, Magela Creek at Mudginberri Billabong Inlet, 18.v.88, Wells & Suter; 4 ♂♂, Radon Springs, 18–19.v.88, Suter & Wells; 9 ♂♂, same data, 14.iv.89; 2 ♂♂, pupae, Magela Creek at Ranger outlet pipe, 20.v.88; 8 ♂♂, pupae, South Alligator River at Fisher Creek confluence, 24.v.88, Wells & Suter; 7 ♂♂, same data, 19–20.iv.89; 5 ♂♂, South Alligator River at Gimbat Station, 28.v.88, Dostine.

Male of this species can be recognised by the broad, sheathing dorsal plate with V-shaped apico-ventral excision, larvae by the spines on the anal prolegs. The pupal case is figured for the first time. *Pupal case* (Fig. 50). Length, 1.4–1.9 mm. Rounded, with short medial ribs, grey.

Distribution: Northern Australia.

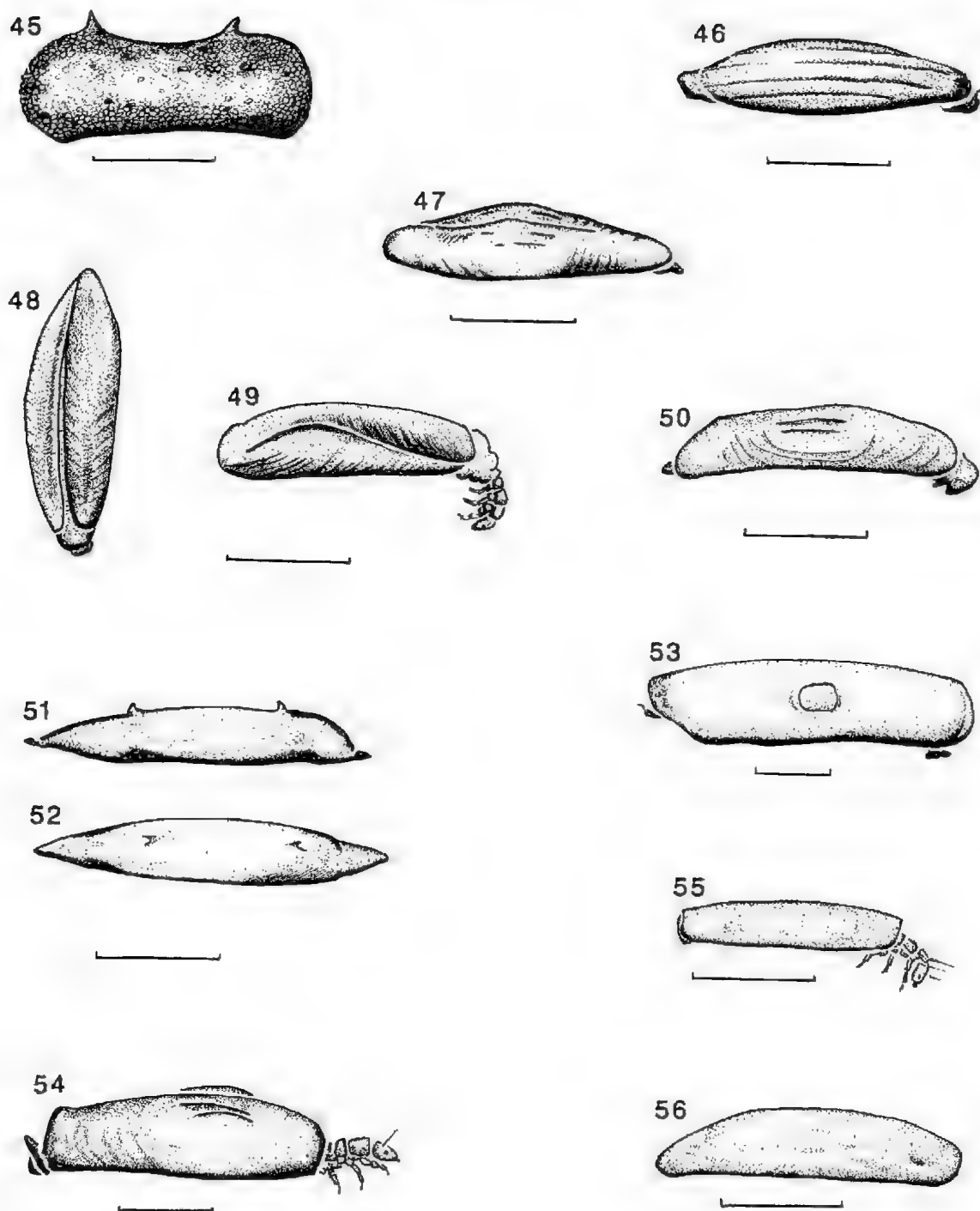
Orthotrichia muscari Wells

FIG. 53

Orthotrichia muscari Wells, 1983, p. 638.

Holotype: ♂, Qld, Iron range, Middle Claudie River, 2–9.x.1974, NMV.

New Records, N.T.: NTM, 1 ♂, 1 ♀, Radon Springs, 14.iv.89, Suter & Wells; 1 ♂ pupa and case, Kakadu National Park, Baroalba Springs, 12°49'S,



Figs 45-56. *Hellyethira forficata* sp. nov. 45, larval case. *Orthotrichia paranga* Wells. 46, pupal case. *Orthotrichia amica* sp. nov. 47, pupal case. *Orthotrichia alata* sp. nov. 48, 49, larval and pupal cases. *Orthotrichia velata* Wells. 50, pupal case. *Orthotrichia tyleri* Wells. 51, 52, pupal case, lateral and dorsal views. *Orthotrichia muscari* Wells. 53, pupal case. *Orthotrichia scutata* Wells, 54, larva and case. *Orthotrichia suteri* Wells. 55, 56, larval and pupal cases. Scale bars = 1 mm.

132°52' E, 22.v.88, Wells & Suter, OSS voucher set; 1 larva, 1 pupa, Magela Creek below falls, 21.iv.89, Wells & Suter; 1 pupa, Baroalba Creek, 17.iv.89 Suter & Wells.

An unusual member of the *aberrans* group of large hydroptilids, with elongate inferior appendages and a brush-like structure arising above the right inferior appendage. Several cased pupae have been collected and conform with others in the group.

Pupa and case. Pupal case length, 4.6 mm. Case large, smooth, transparent, constructed of secretion. In one specimen, one of the two tiny valves of the early final instar larva is incorporated into the later stage case (Fig. 53), others lack the small valves. Pupal cases are covered loosely with coarse sand; pupal hook plates with only one large hook each; anterior margin of the head is produced as in other members of the group (Wells 1985b).

Distribution: Northeastern Qld, northern N.T. Pupae were collected from undersides of rocks in a small, spring-fed stream at the foot of the Kakadu Escarpment.

Orthotrichia constricta sp. nov.

FIG. 43

Holotype: NMV, ♂, NE Qld, Yuccabine Creek, i. 1985, R. G. Pearson & L. J. Benson.

Diagnosis: A new *aberrans* group species, distinguished by the form of its inferior appendages and their dorsal process, and by the narrow sub-apical constriction on the aedeagus which results in a sharp twist at about $\frac{1}{4}$ length.

Description: Male. Anterior wing length, 2.6 mm. Antennae 28-segmented. Genitalia, Fig. 43. Abdominal segment VIII short, broad, sternite produced apico-mesally to form a triangular lobe, tipped with blunt setae. Segment IX narrow, laterally on right produced posteriorly to form a stout spine. Dorsal plate membranous, a broad, blunt, marginal spine on left. Inferior appendages fused, bulbous, slightly cleft mesally; dorsal process undivided, irregular in shape, slightly produced apico-mesally. Aedeagus elongate, tightly constricted and twisted at about $\frac{1}{4}$ length. Paramere a short, twisted spine. Female and immatures unknown.

Distribution: Known only from the type locality, northeastern Qld.

Etymology: From the Latin - *constrictus* - contracted, describing the shape of the aedeagus.

Acknowledgments

R. G. Pearson and L. J. Benson kindly allowed me to study their hydroptilid collection from Yuccabine Creek, NE Queensland.

The office of the Supervising Scientist, Alligator Rivers Region Research Institute funded the project which gave rise to most of the other material used in this work. I wish to thank particularly P. Dostine and C. Humphrey who encouraged me to become involved in work in the Alligator Rivers region, and who, together with P. Suter and P. Cranston, helped with much of the collecting; P. Dostine also made other extensive collections.

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**ROTIFERA FROM AUSTRALIAN INLAND WATERS.
VI. PROALIDAE, LINDIIDAE (ROTIFERA: MONOGONONTA)**

BY W. KOSTA & R. J. SHIEL†*

Summary

Keys are given to the genera and species of the Rotifera: Monogononta of the families Proalidae (four genera) and Lindiidae (one genus). The proalid genus *Wulfertia* is not known from Australia, and a single record of *Bryceella* is doubtful. Two species of *Proalinopsis* and ten species of *Proales* are known from Australian inland waters. *Proales similis exoculis* (Berzins, 1953) is suppressed. Five species of the lindiid genus *Lindia* are confirmed, with a sixth, known from New Zealand, doubtful. All species of these genera recorded from Australian waters are described and figured with known distribution data and ecological information. Brief comments are included on current rotifer taxonomy and biogeography.

KEY WORDS: Rotifera, Proalidae, Lindiidae, Australia, taxonomic revision, biogeography.

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KOSTE, W. & SHIEL, R. J. (1990) Rotifera from Australian inland waters VI. Proalidae, Lindiidae (Rotifera: Monogononta) *Trans. R. Soc. S. Aust.* 114(3), 129–143, 30 November, 1990.

Keys are given to the genera and species of the Rotifera: Monogononta of the families Proalidae (four genera) and Lindiidae (one genus). The proalid genus *Wulfertia* is not known from Australia, and a single record of *Bryceella* is doubtful. Two species of *Proalinopsis* and ten species of *Proales* are known from Australian inland waters. *Proales similis exaculis* (Herzins, 1953) is suppressed. Five species of the lindiid genus *Lindia* are confirmed, with a sixth, known from New Zealand, doubtful. All species of these genera recorded from Australian waters are described and figured with known distribution data and ecological information. Brief comments are included on current rotifer taxonomy and biogeography.

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Introduction

This paper is the sixth of a series reviewing the Rotifera recorded from Australia. The initial purpose of the series was to collate a century of records (much early survey work was done by visitors, and their publications were widely dispersed), bring nomenclature to accepted world standard, and provide usable keys to the known Australian rotifer fauna. As the series has progressed, so too has methodology; advances in light and electron microscopy, biochemical techniques and computing used in studies of the Rotifera worldwide have provided much better resolution of a number of problem areas, including systematics. Some of these advances are documented in the proceedings of triennial symposia on the Rotifera (e.g. Ricci *et al.* 1989), of which there have now been five.

Increasing attendances at these symposia suggest that more researchers are studying rotifers. Some impetus has been provided by the environmental crisis; microscopic aquatic organisms such as Protozoa and Rotifera have been seen as 'early warning systems' for deteriorating water quality, and their morphology, physiology, behaviour, or population characteristics, have been more closely examined. Whatever the reasons, interest in rotifers has expanded, and with it, requests for our revision papers from outside Australia. In view of this more widespread interest, and as a cautionary note to the use of our keys elsewhere, we felt it appropriate to briefly review present rotifer biogeography. At the

suggestion of an anonymous referee, to facilitate comparative studies, we also have included more formal taxonomic details than in the earlier parts.

Biogeography

Global rotifer biogeography and the evidence for vicariance were reviewed by Dumont (1983). He noted that each continent has a distinctive endemic faunule among more widely distributed taxa. Until relatively recently, cosmopolitanism has been promoted by the global use of authoritative taxonomic references (e.g. Ward & Whipple, revised by Edmondson 1963) or the use of figures from the work of respected taxonomists for taxa superficially similar (or not!) but geographically separated. In the Australian context, much of the earlier work was done elsewhere, by workers more familiar with the Rotifera of the northern hemisphere, at a time when rotifers, among others, were widely accepted as cosmopolitan. When competent local workers in Australia began to describe the indigenous species early this century, European reviewers 'cosmopolitanized' these species by synonymy with familiar northern hemisphere taxa.

It has become increasingly evident in our studies of Australian rotifer taxonomy, ecology and distribution that a high degree of endemicity prevails (cf. Koste & Shiel 1987). Methods now exist by which superficially similar taxa can be resolved (cf. Koste & Shiel 1989). These include SEM, as used by Frey (*in press*) for chydorid cladocerans, and electrophoretic methods, as used by Benzie (1988) for *Daphnia*. Until such methods are applied to the Australasian Rotifera, caution should be used in identification below family, particularly where evaluation of environmental impacts or

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perturbations is involved. Similar caution should be exercised in use of our keys and figures to identify non-Australian rotifers.

Systematics

The families of Rotifera: Monogononta considered in this part of our revision are predominantly littoral (epiphytic or epibenthic) in affinity, collected in and around vegetation in shallow waters, e.g. billabongs, or at lake margins, where they graze on detritus, bacteria or algae. The Proalidae and Lindiidae are illoricate rotifers, i.e., they lack the firm, sometimes faceted cuticle (lorica) characteristic of most of the rotifer families we have reviewed (cf. Koste & Shiel 1990). On preservation, most illoricate taxa contract into indeterminate spherical 'blobs', and identification is difficult. Specific determination from preserved material therefore relies heavily on comparative morphology of the sclerotized mastax elements (trophi), which appear to be species-specific.

There are difficulties in detailed examination of trophi structure: the trophi of some rotifer genera are minute (<20 µm), with correspondingly tiny components. Bleaching the body tissue away generally leaves the trophi, but delicate parts may be lost, and the three-dimensional orientation of the trophi is disrupted. In view of these difficulties, the details of trophi structure given in previously published works may be only partially accurate, or at worst, useless to interpret trophi morphology. Inadequate descriptions and figures may have passed through several generations of revisions. The recent application of scanning electron microscopy (SEM) to trophi structure (Markevich 1987; Markevich & Kutikova 1989) has improved resolution of components, but the problems of dissociation and disorientation remain.

In the systematic section below we have followed the format of earlier parts. Formal descriptions are modified (generally abbreviated in translation from the original author) with additions in some cases after the most recent reviser's comments (Koste 1978). Keys to families are included in Koste & Shiel (1987), and details of Rotifera outside Australia, including other species of the two families reviewed here, are found in Koste (1978). Information, where available, on type localities and known distribution, is included. Type material *per se* is very limited; some early taxonomists did not make type slides at all, and many extant collections were lost during the destruction in Europe during WWII. Our Australian type material has been or will be lodged in the South Australian Museum, Adelaide (SAM), and our collections, presently housed at the Murray-

Darling Freshwater Research Centre, or as subsamples in the Koste collection, Quakenbrück, ultimately will be deposited at the SAM.

Family Proalidae Bartos

Proalidae Bartos, 1959, 515. (= sub-family Proalidae Remane, 1933 partim).

Illoricate, body swollen, fusiform or vermiform; head and foot clearly defined; corona mostly supraoral; buccal field with rudiments of lateral cilia (*Bryceella* with two long cirri); mastax resembles malleate with different number of unci teeth (1-8), however is used like virgate mastax, with epipharynx present; hypopharynx muscle inserted on mastax wall, not fulcrum; eyespot on brain, sometimes lateral in *Proales*. Of four genera, *Proalinopsis* (2 spp.) and *Proales* (10 spp.) are known from Australia. *Bryceella* (1 sp.) is a doubtful record, and *Wulfertia* has not been recorded here.

Key to genera of the Family Proalidae

1. Corona with stout cirri with which the animal moves rapidly in a jerky motion; head with rostrum; body fusiform or pear-shaped with transverse pseudosegmentation; unci 5-7 toothed. *Bryceella* Remane.
- Corona without cirri. 2
- 2(1). Head long, with sulci; corona reduced, without lateral ciliary tufts; toes short, wide and acute; body fusiform, widening at beginning of posterior 1/3; cuticle with longitudinal pleats; unci 5-toothed; large epipharyngeal plate. *Wulfertia* Donner
- Corona with lateral ciliary tufts. 3
- 3(2). Spinulate papilla above cloaca; unci 8-9 toothed. *Proalinopsis* Weber
- No papilla above cloaca; unci 1-6 toothed. *Proales* Gosse

Genus *Bryceella* Remane

Bryceella Remane, 1929, p. 115

Type: *Stephanops stylatus* Milne, 1886 = *Bryceella stylata* (Milne).

Type locality: Moss, near Glasgow, Scotland.

Bryceella is isolated systematically by the possession of peculiar cirri assemblages on the corona. Body slender; anterior end oval, with neck clearly defined, head extended anteriorly (rostrum); abdomen oval, with narrow preanal section and short, squat tail; foot slender, with 2-3 pseudosegments; toes blunt, slender, curved ventrally; integument relatively stiff; abdomen with lateral longitudinal sulci; trophi small, of modified malleate type; manubria with lateral lamellae; unci with 5-7 teeth; rami with teeth on inner margin as well as basalapophysis; cirri of corona stand in several transverse rows and serve in locomotion

(reminiscent of the ciliate *Euplotes*); animal proceeds jerkily, with longest cirri to the front; laterally, a pair of extremely long sensory setae project from the head.

Distribution: *B. stylata* (Milne, 1886) (Fig. 1:1) is known from the Palaearctic, and *B. tenela* (Bryce, 1897) (Fig. 1:2) is known more widely from acid waters of North and South America, Europe, Asia and New Zealand. *B. voighti* was described from Romania by Rodewald (1935), however the figures and description were unsatisfactory, and the status of this taxon was queried by Koste (1978). The single-toothed uncus, lack of inner-margin teeth of the rami, apparent absence of long lateral setae and differences in the morphology as figured, make placement of *B. voighti* doubtful.

Australian record: The only record is of *Bryceella voighti* by Berzins (1982) from two localities at Bombala, N.S.W. (28.xii.49 and 8.i.50), both from moss on *Eucalyptus* trunks. No figures or description were given, hence we regard it as an unverified record of an indeterminate taxon.

Genus *Proaliniopsis* Weber

Proaliniopsis Weber in Weber & Montet, 1918, p. 98.

Type: *Notommata caudata* Collins, 1872 = *Proaliniopsis caudatus* (Collins)

Type locality: pools, Sandhurst, Berkshire, England.

Body elongated, illoricate, cuticle very transparent, adult sometimes with filamentous gelatinous envelope; head and foot clearly demarcated; body cross-section hemispherical; dorsal antennae on cuplike-cylindrical papillae; gibbous rump protrudes as a rim over foot; foot two-segmented, proximal segment longest, with dorsal knob bearing a long spine or setal tuft; corona an oblique disc with short marginal cilia and two lateral areas with long cilia; lateral antennae with long sensillae, on small protuberances, at level of upper intestine; long pointed toes, elongated foot glands; mastax intermediate between malleate and virgate trophi; fulcrum slender, laterally dagger-like; rami symmetrical, large and triangular, without teeth or alulae; uncus with ca. eight long, thin teeth, clubbed at tips; epipharynx absent; eyespot, if present, cervical. Seven species are known (Koste 1978), two of which have been recorded from Australia.

Key to species of the genus *Proaliniopsis* known from Australia

Fine needle-like spinules on posterior dorsal papilla.
..... *P. caudatus* (Collins)
Papilla with robust spine.
..... *P. staurus* Harring & Myers

Proaliniopsis caudatus (Collins)

FIG. 1:3

Notommata caudata Collins, 1872, p. 11, Fig. 8

Proaliniopsis caudatus: Weber & Montet 1918, p. 98.

Type locality: Pools, Sandhurst, Berkshire, England.
Holotype: Not designated.

Description: Body slender, bulging posteriorly, width $< \frac{1}{4}$ length; head narrow, separated from neck by transverse fold; bright red cervical eyespot; abdomen ends in short tail projecting over foot; foot two-segmented, fusiform; proximal segment with dorsal knob bearing long deflexed setae; toes long, acute, slightly curved; foot glands small and slender; mastax virgate, resembles malleate; eight teeth on left, seven on right uncus, ventral tooth in each case largest and clubbed, remaining teeth decreasing dorsally.

Length: 125–268 μm ; width to 77 μm ; toes 16–22 μm ; trophi 18 μm wide, 25 μm long; manubrium 18 μm ; fulcrum 7 μm ; unci 11 μm ; subitaneous egg 60 \times 30 μm .

Ecology: Widely distributed, probably cosmopolitan in slightly acid waters (pH 4.5–6.5). *Sphagnum* pools. Rare, N.S.W., W.A.

Literature: Koste (1978).

Proaliniopsis staurus Harring & Myers

FIG. 1:4

Proaliniopsis staurus Harring & Myers, 1924, p. 439–40.

Fig. 20: 5–9.

Type locality: No single locality specified; In 'floating and submerged *Sphagnum* in soft water lakes and ponds', Mamie Lake, Eagle River and Lac Vieux Desert, Vilas County, Wisconsin, also New Jersey and Florida, U.S.A.

Holotype: ?Myers Coll., USNMNH, New York.

Description: Body fusiform; deep constriction separates head from abdomen; no red cervical eyespot; abdomen tapers gradually to tail; foot two-segmented, proximal segment with dorsal knob bearing single stout spine; toes stout at base, acute; foot glands large, pyriform; mastax virgate, resembles malleate; unci with eight or nine clubbed teeth, decreasing dorsally.

Length: 100 μm ; toes 18 μm ; trophi 15 μm .

Ecology: Only known previously from *Sphagnum* in North America. Two Australian records; L. Tidler (Gordon R.) and a stock dam at Golden Valley, Tas. 18.0–25.0°C, pH 5.8–7.8, 40.8–46.6 $\mu\text{S cm}^{-2}$, TDS 26.1 mg l^{-1} , 1.9 NTU.

Literature: Koste (1978); Koste *et al.* (1988).

Not recorded from Australia;

P. gracilis Myers, 1933, U.S.A.; *P. lobatus* Rodewald, 1935, Europe; *P. phagus* Myers, 1933 U.S.A.; *P.*

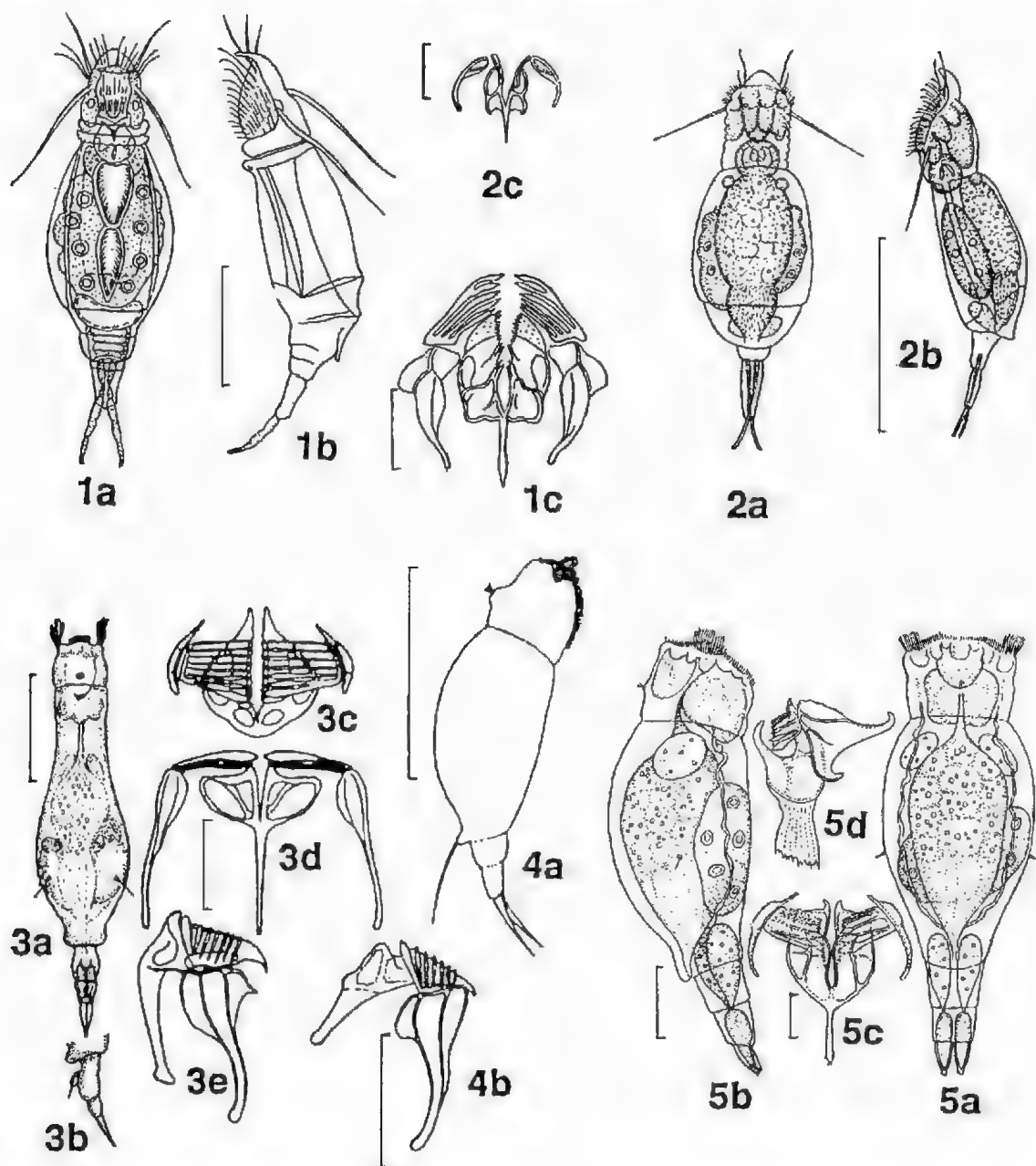


Fig. 1. 1, *Bryceella stylata* (Milne): (a) dorsal; (b) lateral; (c) trophi. 2, *B. tenela* (Bryce): (a) dorsal; (b) lateral; (c) trophi. 3, *Proalinopsis caudatus* (Collins): (a) dorsal; (b) foot and toes, lateral; (c) trophi, dorsal; (d) trophi, ventral; (e) trophi, lateral. 4, *P. staurus* Harring & Myers: (a) lateral; (b) trophi, lateral. 5, *Proales daphnicola* Thompson: (a) lateral; (b) dorsal; (c) trophi, ventral; (d) trophi, lateral. 1 after Wulfert (1940); 2 after Kutikova (1970); 3–5 after Harring & Myers (1924). Scale lines: adult 50 μ m, trophi 10 μ m.

selene Myers, 1933. U.S.A.; *P. squamipes* Hauer, 1935. Europe.

Genus *Proales* Gosse

Proales Gosse in Hudson & Gosse, 1886, 2, p. 36.

Type: *Notommata decipiens* Ehrenberg, 1832 = *Proales decipiens* (Ehrenberg).

Type locality: near Berlin, FRG.

A diverse series of taxa, from free-living to parasitic, freshwater to halophile. Fusiform illoricate body in free-living species, more swollen in parasitic taxa (also considerable distortion of the body in females bearing resting eggs); head separated from abdomen by slight constriction behind mastax; foot indistinct, very short to long and articulated; two toes; corona generally oblique, ciliary disc with short marginal cilia and two lateral tufts of long cilia (not contractile auricles as in *Lindia* or *Notommata* species); mastax modified malleate-virgate type; trophi very small.

Comment: *Proales* requires thorough revision; the diversity of taxa presently included in the genus undoubtedly will separate into more uniform groups with improvements in taxonomy, e.g. SEM study of trophi morphology as by Markevich (1987). Of 30 species recorded globally, 10 are known from Australia.

Key to species of the genus *Proales* known from Australia

1. Foot with single toe... *P. dallaris* (Rousselet)
- Foot with two-toes... 2
- 2(1). Eyespot below base of brain; body bulbous; toes coniform; commonly epizoa on *Daphnia*... *P. daphnicola* Thompson
- Eyespot, body and toes not as above; not epizoa on *Daphnia*... 3
- 3(2). Parasitic in colonies of *Volvox* or in *Vaucheria* cells... 4
- Free-swimming, not parasitic... 5
- 4(3). In *Volvox* colonies (not to be confused with *Ascomorphella volvocicola*); trophi small (to 15 µm) ... *P. parasita* (Ehrenberg)
- In *Vaucheria* filaments... *P. wernecki* (Ehrenberg)
- 5(3). Toe:body ratio >18... 6
- Toe:body ratio <17... 7
- 6(5). Trophi <30 µm; small dorsal knob between toes... *P. fallaciosa* Wulfert
- Trophi >30 µm; pointed spine on dorsal margin of foot... *P. gigantea* (Gosse)
- 7(5). Foot long (2-3× toe length)... *P. sentida* Gosse
- Foot short (<2× toe length)... 8
- 8(7). Eyespot absent; body vermiform... *P. micropus* (Gosse)
- Eyespot present, median or laterally displaced; body fusiform... 9
- 9(8). Median eyespot, ventral to base of brain, no lens, 6 unci teeth... *P. similis* De Beauchamp
- Eyespot displaced to right, crystalline lens; 4/5 unci teeth... *P. decipiens* (Ehrenberg)

Proales daphnicola Thompson

FIG. 1:5

P. daphnicola Thompson, 1892, p. 220, Fig. 125.

Type locality: (England)

Holotype: Not designated.

Description: Body short, stout, widest medially with marked constriction behind head, fusiform thereafter; corona slightly oblique, with two lateral strongly-ciliated areas corresponding to auricles in notommatalids; integument soft, flexible; foot short, stout, two-segmented, with two short coniform toes, swollen at the base, with tubular spinules; reddish eyespot at underside of brain; trophi malleate with five clubbed unci teeth, rami with unusual doubled hornlike, conical, elongated spikes; oesophagus long, slender, gastric glands large; foot glands large, pyriform, with reservoirs in distal and proximal foot segments; subitaneous egg smooth; resting egg light-brown, covered in hooks. Male similar in form to female, slightly smaller.

Length 275-400 µm, toes 25-30 µm, trophi 36-40 µm, unci to 18 µm, subitaneous egg 96×30 µm, resting egg 105-109×76-80 µm.

Ecology: Widely distributed epizoa on *Daphnia* spp., where it feeds on flagellates and ciliates living on the carapace. Regarded in early literature as 'entozoically parasitic' (Hudson & Gosse 1886). Eggs generally are attached to the bases of the cladoceran's antennae (Koste 1978). Europe, Asia, N. America, Africa. Only known localities in Australia are from R. Murray billabongs near Albury-Wodonga on *D. carinata* and *D. cephalata*. 10.2-15.3°C, pH 6.9-7.9, DO 7.1-12.4 mg l⁻¹, 78-170 µS cm⁻¹, 4.0-39.0 NTU.

Literature: Harring & Myers 1924; Koste 1978.

Proales decipiens (Ehrenberg)

FIG. 2:1

Notommata decipiens Ehrenberg, 1832, p. 132.

Proales decipiens: Hudson & Gosse 1886, 2, p. 36

Type locality: near Berlin, FRG.

Holotype: Not designated.

Description: Body elongate, slender, transparent; trunk widest in posterior third, tapers to two-segmented foot bearing two toes with acute points; integument with longitudinal folds; transverse folds demarcate head and neck from trunk; corona oblique with lateral ciliary fields; eyespot small, red, mostly displaced to right; distinct bubble-like retrocerebral sac; gastric glands oval or lobate; mastax with virgate trophi, but resembling malleate type; rami with large basal apophysis, on which are asymmetric teeth medially; no alulae; unci with 5/5 and 4/5 webbed teeth, the largest bifurcate, decreasing in size dorsally; epipharynx two hammer-

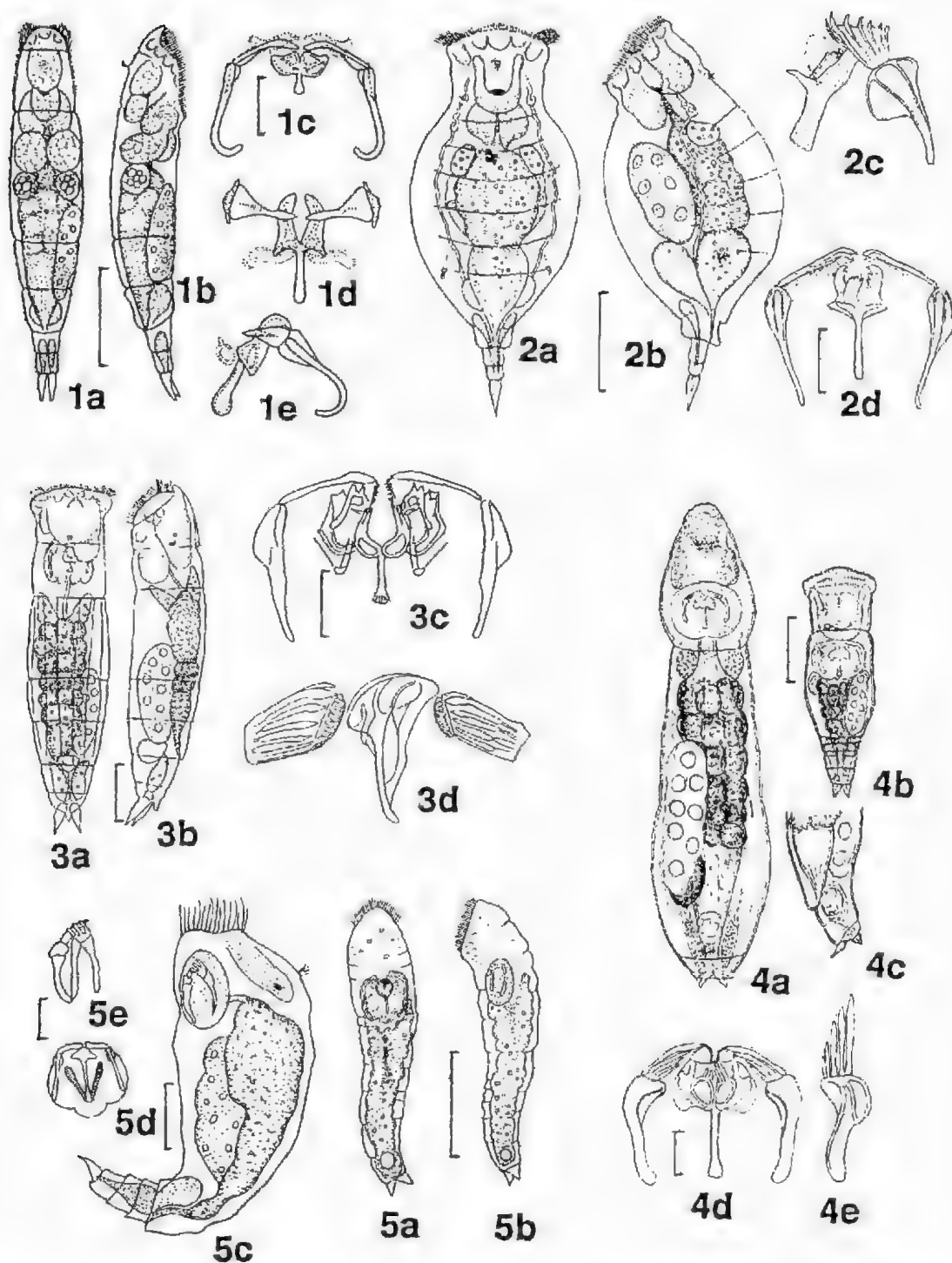


Fig. 2: 1, *Proales decipiens* (Ehrenberg): (a) dorsal; (b) lateral; (c-e) trophi, various aspects. 2, *P. doliaris* (Rousselet): (a) dorsal; (b) lateral; (c-d) trophi. 3, *P. fallaciosus* Wulfert: (a) dorsal; (b) lateral; (c-d) trophi. 4, *P. gigantea* (Glasscott): (a) dorsal; (b) juvenile; (c) posterior showing tail and toes; (d) trophi; (e) manubrium and uncus, lateral. 5, *P. micropus* (Gosse): (a) dorsal; (b) lateral; (c) 2nd individual, lateral; (d-e) trophi. 1, 2 after Harring & Myers (1924); 3 after Wulfert (1939); 4 after Koste (1978); 5 after Hudson & Gosse (1886), as figured by Kutikova (1970). Scale lines: adult 50 μ m, trophi 10 μ m.

like structures; manubrium long, broadly triangular ribbed plates. Male known.

Length: 120–270 μm ; toes 10–16 μm ; trophi 15–21 μm .

Ecology: Cosmopolitan among vegetation, in small water bodies, billabongs, ponds. Rare; Tas., Vic. 10.2–21.0°C, pH 7.2–7.6, 11.8–57.3 $\mu\text{S cm}^{-1}$, DO 9.0 mg l⁻¹, 4.0–5.0 NTU

Literature: Harring & Myers (1922); Koste (1978).

Proales doliaris (Rousselet)

FIG. 2:2

Microcodides doliaris Rousselet, 1895, p. 120, Fig. 7:4

P. doliaris: Harring & Myers 1924, p. 437, Fig. 19:3–7.

Type locality: U.K.

Holotype: Not designated.

Description: Cuticle soft and transparent; trunk oval to round in section; foot two- or three-segmented; two foot glands; indistinct reddish cerebral eyespot; corona oblique with supraoral buccal field; complete circumapical ciliation and lateral ciliary bundles; right uncus with seven, left uncus with six teeth; inner margin of rami with asymmetric hooklike denticles, externally with wide lamellae; retrocerebral organ absent.

Length: 170–300 μm ; toes 20–25 μm ; trophi 20–25 μm .

Ecology: Widespread (Europe, North America, New Zealand, Asia); Not seen in our material. Berzins (1982) recorded it from Sunbury, Vic.

Literature: Koste (1978).

Proales fallaciosus Wulfert

FIG. 2:3

Proales fallaciosus Wulfert, 1937, p. 65, Fig. 4; 1939, p. 597, Fig. 12.

Type locality: Bad Lauchstädt, FRG.

Holotype: Not designated.

Description: Variable morphology, body cylindrical with medial bulge, tapers to truncated two segmented foot with two conical toes; small rounded knob projecting dorsally between toes; cuticle generally with longitudinal folds; corona oblique, laterally with strong ciliary tufts rather than auricles; small rostrum present; hemispherical retrocerebral sac and red eyespot displaced to right; trophi primitive virgate type resembling malleate: left uncus with seven teeth, right with 5–6 teeth; fine denticles directed inwards along tooth-plate margin (Fig. 2:3c); rami with basal apophysis drawn into 2–3 points; no alulae; manubrium with shorter inner lamella and outer inwardly curving wider lamella; gastric glands round to elongated; foot glands with reservoirs.

Total length 200–320 μm ; toes 9–15 μm ; trophi 25–28 μm ; fulcrum 6–11 μm ; rami 9–12 μm ; unci 9–15 μm .

Ecology: Cosmopolitan in alkaline to slightly acid water, particularly decomposing macrophytes, where it feeds on detritus, bacteria and algae, also on decomposing microcrustaceans and macroinvertebrates. Often confused with *P. decipiens* or *P. sordida* (Koste 1978). Only known from Tasmania: stock dam near Huemville, 9.0–16.0°C, pH 5.7–7.6, 13.4–415 $\mu\text{S cm}^{-1}$, 0.6–0.7 NTU.

Literature: Koste (1978); Koste & Shiel (1986).

Proales gigantea (Glasscott)

FIG. 2:4

Notommata gigantea Glasscott, 1893, p. 80, Fig. 7.

Proales gigantea: Stevens 1912, p. 481, Fig. 24:1–5.

Type locality: (Ireland).

Holotype: Not designated.

Description: Body cylindrical, very flexible in living animal; clearly defined constriction behind mastax; trunk dilates distally to wide, short foot terminating in two short, conical toes; pointed spur on posterior dorsal margin of foot; mastax with asymmetric malleate-type trophi; uncus straight; fulcrum long, with slight terminal curvature; manubrium with short lamella at head; rami broad, triangular, right ramus only with broad denticulate blade opposing first tooth of left uncus; right uncus 5–6 toothed, left 4–5 toothed; no alulae; gastric and foot glands elongated, fusiform.

Length: 140–510 μm ; toes 8–12 μm , trophi length 30–35 μm , unci to 19 μm , manubrium 18 μm , subitaneous egg 150 \times 50 μm .

Ecology: Europe, N. America, N.Z. Parasitic in pond snail eggs (e.g. *Lymnaea*, *Radix*). Young female pierces egg shell, lays eggs, juvenile *P. gigantea* eat the snail embryo. A 140 μm juvenile leaving an eggshell can reach 510 μm in 5–6 days (Koste 1978). We have not encountered this animal in our Australian material, however Laird (1956, verified by Russell 1957) recorded it free-swimming from a ponded stream near Rollingsstone, Queensland (19°03'S/146°24'E).

Literature: Harring & Myers (1924).

Proales micropus (Gosse)

FIG. 2:5

Furcularia micropus Gosse in Hudson & Gosse, 1886, 2, p. 46, Fig. 19:12.

Proales micropus: Jennings 1901, p. 743, Fig. 5:82

Type locality: A ditch near Birmingham, England.

Holotype: Not designated.

Description: Small cylindrical vermiform body, colourless, illoricate, very pliable and variable in living animal; trunk tapers to minute conical toes almost as wide as long; toes with inner convexity, commonly deflected ventrally; corona oblique; eyespot occasionally present; small rostrum may be extended; uncus with three teeth; epipharynx with two small plates.

Length: 100–150 μm , toes 6–9 μm , trophi 14–16 μm .

Ecology: Rare in periphyton, on *Chara* in ponds and lakes, Europe, N. America. Not seen in our material. Single unconfirmed record from Queensland by Colledge (1911).

Literature: Koste (1978).

Proales parasita (Ehrenberg)

FIG. 3:1

Notommata parasita Ehrenberg, 1838, p. 426, Fig. 50:1.

Proales parasita: Rousselet 1911, p. 8.

Type locality: Near Berlin, FRG.

Holotype: Not designated.

Description: Body short and stout, integument flexible; head and neck marked by transverse folds; trunk dilated posteriorly, tapering to foot; tail a rounded median lobe; foot broad, indistinctly two-segmented; toes wide at base, conform to acute points; corona with two lateral ciliary tufts; brain quadratic with hemispherical retrocerebral sac; red eyespot at end of brain; Wulfert (1960) reported red crystalline bodies in a light sensitive organ, displaced to right; mastax small, epipharynx two slender curved rods; trophi modified virgate type; basal apophysis a semicircular plate; unci 3-toothed, teeth joined by thin lamellary web; rami asymmetric, more developed on right than left, without alulae; manubria with broad plates anteriorly, continue as slender, curved rods; gastric glands small; stomach commonly filled with green or dark red-yellow food mass; separate intestine; foot glands large, sausage-shaped with reservoirs; resting egg covered with short, strong spines.

Length 140–180 μm , toes 10 μm , trophi 15 μm , subitaneous egg 64 μm , male 40 μm .

Ecology: Europe, N. America, Asia. Lives in colonies of *Volvox*, *Ophridium*, *Uroglena*, occasionally confused with *Ascamorphella volvocicola*, which its behaviour resembles. Eggs laid in algal colony; young animals and parent graze individual algal cells, eventually swim from the ruptured colony to seek fresh colonies. Not seen in our material. Recorded by Whitelegge (1889) from N.S.W., and by Colledge (1914) from Queensland. These records may represent *A. volvocicola*.

Literature: Harring & Myers (1922); Koste (1978).

Proales similis De Beauchamp

FIG. 3:2

Proales similis De Beauchamp, 1907, p. 153, Fig. 2.

Type locality: (France).

Holotype: Not designated.

Description: Body elongate transparent cylinder, slightly dilated medially, tapering to comparatively long wrinkled foot and toes; ruby-red eyespot behind brain, medial, displaced ventrally; retrocerebral sac small, ductless; stomach and intestine not clearly separated; mastax light brown; epipharynx two long curved rods in anterior mastax wall; trophi intermediate between virgate and malleate; rami triangular, without denticulation on inner edge; short, pointed alulae present; fulcrum short; unci with six teeth, last two on dorsal margin partly fused (NB: 4–5 teeth were reported by De Beauchamp 1908 and 6–7/8–9 by Wulfert 1942); foot glands small, pyriform, with small mucus reservoir at base of toes.

Length 125–180 μm , toes 7–20 μm , trophi 18–24 μm .

Ecology: Halophile, in athalassic saline, estuarine and brackish waters, Europe, N. America. Single record from Diana's Basin near St Helens, Tasmania 19.0°C, pH 8.9, 34.8 mS cm^{-1} .

Comment: A variant described by Berzins (1953) as *P. similis* var. *exoculis*, from saline (ephemeral) waters near Tammin, W.A., is here synonymised. Its measurements fall within the range of *P. similis*. The lack of an eyespot as noted by Berzins is probably a preservation artefact.

Literature: Koste (1978).

Proales sordida Gosse

FIG. 3:3

Proales sordida Gosse in Hudson & Gosse, 1886, 2, p. 37, Fig. 18:7.

non *P. sordida*: Harring & Myers 1922, p. 605, Fig. 51:9–12.

Type locality: Not specified. 'Many localities in England and Scotland: common in pools.'

Holotype: Not designated.

Description: Squat, head slightly flared anteriorly; head and neck marked by transverse folds; trunk almost cylindrical, tapering to 3-segmented foot with rounded distal segment projecting over swollen bases of stout toes; foot with median longitudinal depression; corona oblique; numerous vesicles in anterior of head; large hemispherical retrocerebral sac; brain with lateral ruby-red eyespot; stomach and intestine not separated; foot glands large with reservoirs; unci with five teeth; rami with large alulae; epipharynx unciform with characteristic basal plate.

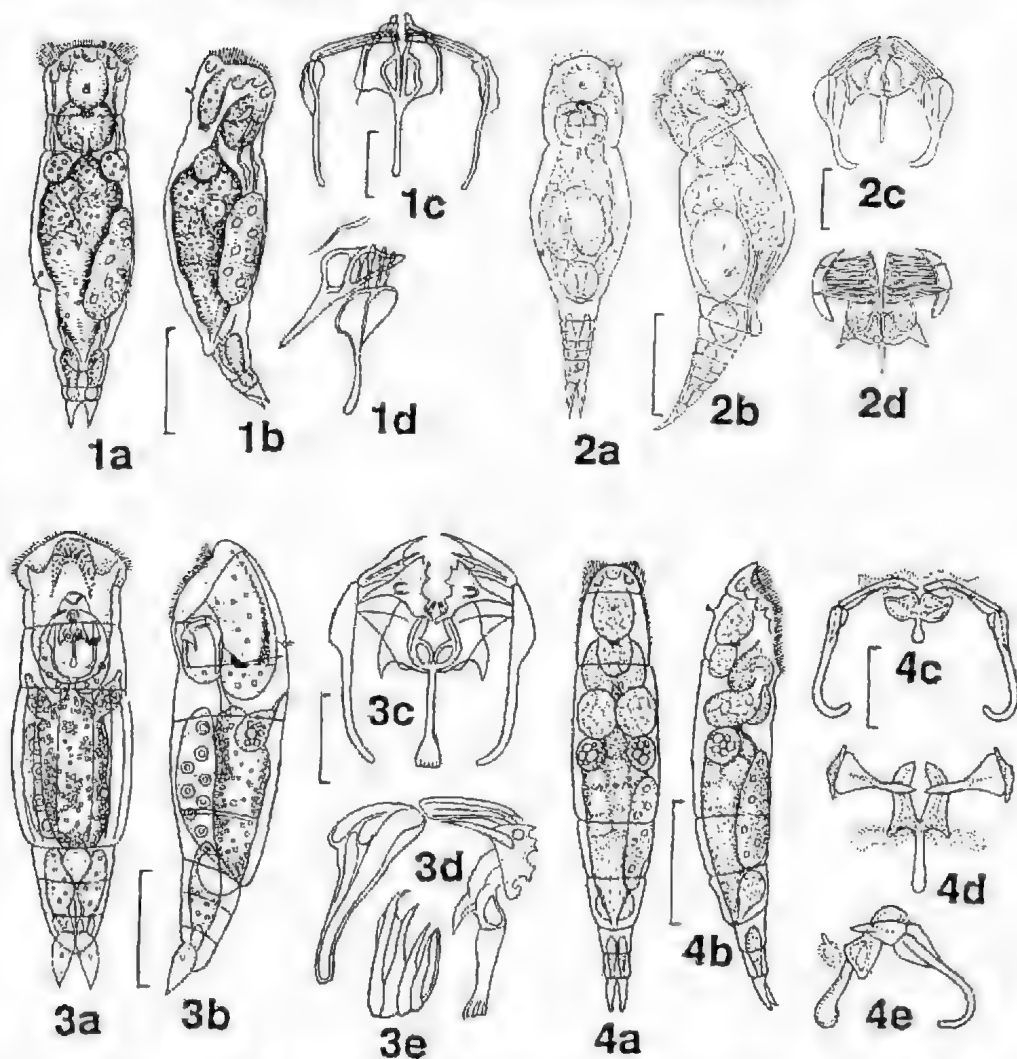


Fig. 3: 1, *Proales parvita* (Ehrenberg): (a) dorsal; (b) lateral; (c-d) trophi. 2, *P. similis* De Beauchamp: (a) dorsal; (b) lateral; (c-d) trophi. 3, *P. sordidus* (Gosse): (a) dorsal; (b) lateral; (c-d) trophi. 4, *P. wernecki* (Ehrenberg): (a) dorsal; (b) lateral; (c-e) trophi, various aspects. 1 after Harring & Myers (1924); 2 Koste, orig.; 3 after Wulfert (1939). Scale lines: adult 50 μ m, trophi 10 μ m.

Length: 150–230 μ m, toes 10–12 μ m, trophi 25 μ m, fulcrum 12 μ m, unci to 12 μ m, manubrium to 20 μ m.

Ecology: Cosmopolitan, in periphyton and diatom films. Not seen in our material; recorded by Colledge (1911) from Queensland and Evans (1951) from Victoria.

Literature: Koste (1978).

Proales wernecki (Ehrenberg)

FIG. 3:4

Notommata werneckii Ehrenberg, 1834, p. 216.

Proales werneckii: Hudson & Gosse 1889, p. 23, Fig. 32:18.

Type locality: Near Dassau, FRG.

Holotype: Not designated.

Description: Body elongate, transparent, very slender; integument flexible; head longer than wide, rounded anteriorly, slight constriction demarcating neck; body cylindrical, tapering to 2-segmented foot with slightly decurved conical toes; corona oblique with lateral ciliary tufts; retrocerebral sac present; mastax with salivary glands; epipharynx two sigmoid plates embedded in mastax wall near base of rami; trophi resemble malleate type; rami triangular, decurved at posterior ends; unci single-toothed; manubria with small anterior lamellae, elongate with hooked ends curving diagonally

inwards; gastric glands large, filled with refractive globules; stomach not separated from intestine; retrocerebral sac present; eyespot posterior to brain. Resting egg with smooth shell.

Length: 140–200 μm , male 128–150 μm , toes 11–16 μm , trophi 12–18 μm , subitaneous egg 65–87 μm , resting egg 62–72 μm .

Ecology: Parasitic in filaments of *Vaucheria* spp., the cells of which form galls around the rotifer, which subsists on chloroplasts, cytoplasm and oils produced by the alga. Up to 80 subitaneous eggs produced by the female in the gall, where she subsequently dies. Young animals leave the gall; copulation is outside the host, with resting eggs produced overwintering in the sediments. Europe, North America. Two Australian records: Sydney (Whitelegge 1889) and Macquarie Marshes, N.S.W. (F. Crome unpubl.)

Literature: Koste (1978). For species not recorded from Australia, see Koste (1978: 267–284).

Family Birgeidae Remane, 1937

Not recorded from Australia (see Koste 1978: 284–5)

Family Lindiidae Remane, 1933

Vermiform or fusiform rotifers in general appearance and coronal form resembling *Notommata* (Notommatidae); mastax cardate; manubria with characteristic hooked structure. Remane (1933) separated *Lindia* Dujardin, 1841 into two subgenera, *Lindia* (s. s.) and *Lindia* (*Halolindia*), which, although having comparable trophi structure, have marked differences in body- and coronal-form, also in ecology. *Lindia* (s. str.) occurs in freshwater, and is oviparous. *L. (Halolindia)* occurs in marine or athalassic saline waters, and is viviparous. Five species of *Lindia* (s. s.) are known from Australia, none of *L. (Halolindia)*. *Lindia parrotti* Russell, described from New Zealand, also may occur here.

Genus *Lindia* (s. s.) Dujardin

Lindia Dujardin, 1841, p. 653.

Type locality: (France).

Body cylindrical or fusiform; head with lateral, medium to very long, ciliary auricles (not everted under pressure of coverslip in mounted preparations); head and neck delineated by transverse sutures, which also occur along trunk, but most obviously on tail; foot short, stout, two-segmented, cylindrical with short acute conical toes; trophi with small 2–4 toothed unci; manubria with

dorsal projecting plate; hook-, strut- or sickle-shaped structures; preuncial teeth in several species; conspicuous epipharynx generally present; hypopharynx muscle, when present, rudimentary; salivary glands present in *L. truncata*; stomach and intestine indistinctly separate; gastric glands mostly large; protonephridia and retrocerebral sac without structure; subcerebral glands absent; cerebral eyespot always present.

Key to species of *Lindia* known from Australia

1. Body <100 μm ; trophi <10 μm *L. parrotti* Russell
- Body >100 μm ; trophi >10 μm 2
- 2(1). Toes >30 μm *L. eccla* Myers
- Toes <30 μm 3
- 3(2). Distinct bilateral spherical protrusions of integument in contracted individuals (Fig. 4:2b); trophi >50 μm long..... *L. deridderi* Koste
- No obvious protrusions; trophi <50 μm long..... 4
- 4(3). Trophi <20 μm *L. annecta* Harring & Myers
- Trophi >20 μm 5
- 5(4). Head with rostrum; toes cylindrical with offset short points; elongate ciliated auricles (Fig. 4:4a); trophi 26–32 μm *L. torulosa* Dujardin
- Head without rostrum; toes conical, tapered; ciliary auricles short (Fig. 4:5a); trophi 30–43 μm
- *L. truncata* Jennings

Lindia annecta Harring & Myers

FIG. 4:1

Lindia annecta Harring & Myers, 1922, p. 622–624, Fig. 54: 6–9

Type locality: No single locality specified. '... *Sphagnum* bogs and ditches near Atlantic City, New Jersey.'

Holotype: ?Myers Coll., USNMNH, New York.

Description: Body slender, transparent, transverse folds give annular appearance; head and neck sections of similar length and width; trunk widest posteriorly, tapering to indistinctly 3-lobed rump. Two-jointed foot, short, conical, acute toes; corona extends ventrally ca. 1/5th of body length; lateral auricles small, widely tongue-shaped as in many *Notommata* species; rudimentary salivary glands, large gastric and food glands; brain large, saccate, with posterior retrocerebral organ encasing distinct red eye-spot, scattered pigment granules; mastax specialized virgate type: fulcrum short, quadrate; manubria with wide lamellae, before hooked appendage; unci with three teeth, median twice as long and more strongly developed than two laterals, all three joined by elongate plate.

Length: 300–350 μm ; toes 15–18 μm ; trophi 18 μm long, 30 μm wide.

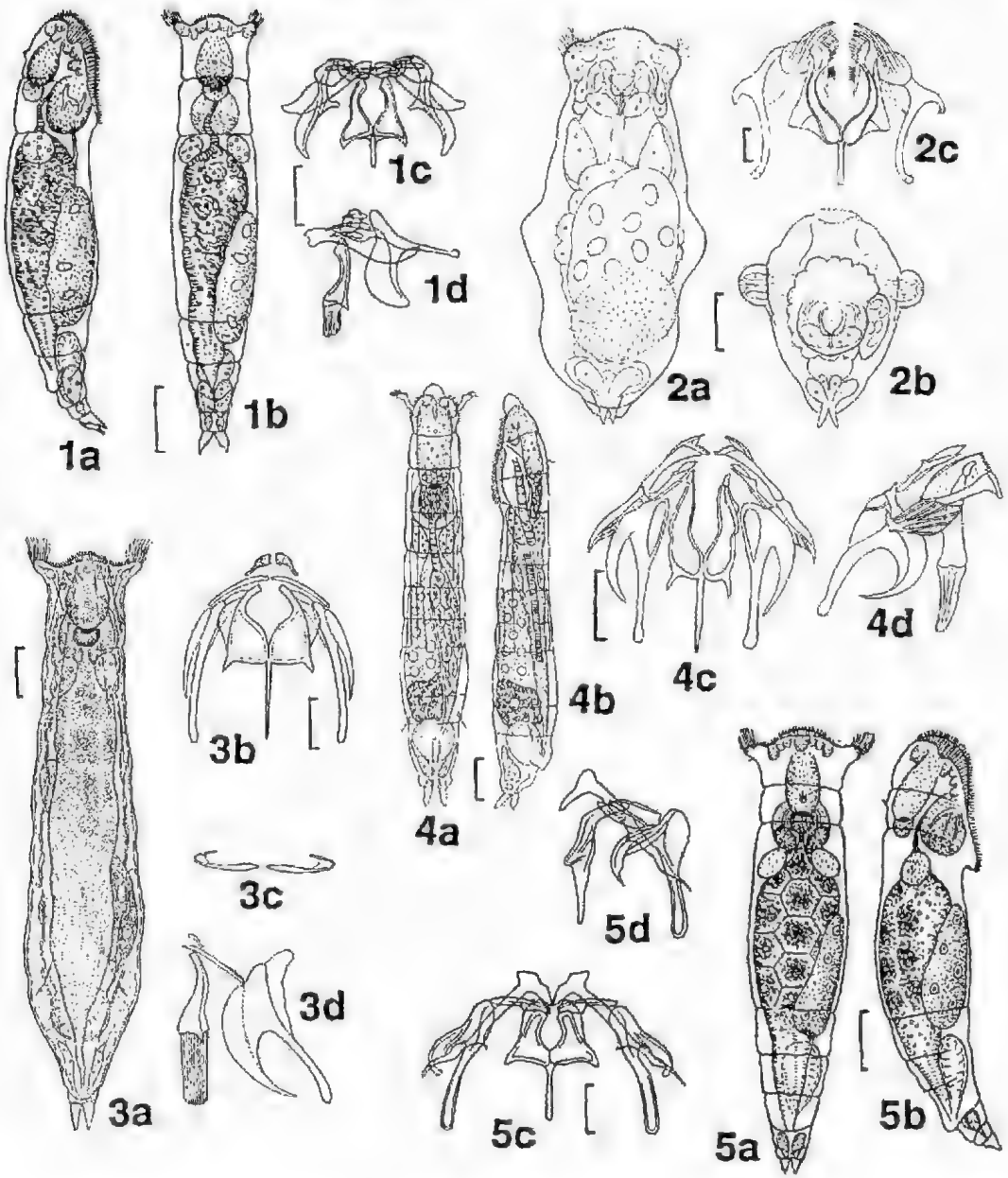


Fig. 4: 1, *Lindia anneeta* Harring & Myers: (a) lateral; (b) dorsal; (c-d) trophi. 2, *L. deridderi* Koste: (a) dorsal, slightly contracted; (b) fully contracted; (c) trophi, ventral. 3, *L. ecela* Myers: (a) dorsal; (b) trophi, ventral; (c) unci, frontal; (d) trophi, lateral. 4, *L. torulosa* Dujardin: (a) dorsal; (b) lateral; (c-d) trophi. 5, *L. truncata* (Jennings): (a) dorsal; (b) lateral; (c-d) trophi. 1, 4 after Harring & Myers (1922); 2 after Koste (1981); 3 after Myers (1933); 5 after Wullert (1939). Scale lines: adult 50 μ m, trophi 10 μ m.

Ecology: Most abundant in *Sphagnum* and periphyton. Single unconfirmed Australian record from 2000 m, Mt Buffalo, Vic. (Berzins 1982).
Literature: Koste (1978).

Lindia deridderi Koste

FIG. 4:2

Lindia deridderi Koste, 1980, p. 504–511, Figs 1–4.

Type locality: Ryan's 1 billabong, Wodonga, Vic. (36°07'S, 146°53'E).

Holotype: Holotype trophi only and three paratype trophi preparations lodged with the Type Collection, Zoological Museum, University of Kiel, F.R.G., Nos. Rot 15–18.

Description: Fusiform body with distinctive paired lateral protrusions of integument (more obvious in contracted individuals), trunk broadly rounded to rump projecting over single segmented foot and conical toes; head and neck distinctly pseudosegmented by dorsal annular creases, which also occur (less distinctly) on trunk; corona of *Notommata* type; oval salivary glands, very large elliptical gastric glands; large retrocerebral sac and eye spot present; mastax with specialized cardate trophi, with distinct paired hypopharyngeal muscles unique to genus binding fulcrum and rami; rami sickle-shaped, acutely pointed, bearing two small pointed teeth; unique to *L. deridderi* also are the widened tips of the rami, forming spoonlike extensions bearing 11 small, sharp teeth (Fig. 4:2c) below the inwardly directed main teeth; unci plates with four longer rod-like teeth, beneath which are 6–7 denticles on a rod-like structure, possibly functioning in opposition to the rami-processes (?preuncinal teeth). Subitaneous egg spiny.

Length: 300–400 µm; toes 14–20 µm; trophi 53 µm long, 60 µm wide; fulcrum 12 µm; rami 29–32 µm; longest uncus tooth 16–20 µm; manubrium 40 µm; subitaneous egg 136 × 100 µm with 12–16 µm spines.

Ecology: Endemic. Recorded only in billabongs on the R. Murray floodplain between Wodonga and Yarrowong, Vic. Often with cyanobacterial remains in gut. 10.2–17.5°C, pH 6.8–7.2, DO 7.3–9.0 mg l⁻¹, 108–145 µS cm⁻¹, 4.0 NTU.

Lindia evela Myers

FIG. 4:3

Lindia evela Myers, 1933, p. 8–9, Fig. 5.

Type locality: Mt Desert Island, Maine, U.S.A., among *Nitella* and *Botrachospermum* in permanent bodies of acid water.

Holotype: Myers Coll., USNMNH, New York.

Description: Body elongate; cylindrical, slender, integument very flexible; head small, neck fold indistinct; abdomen swollen posteriorly, tapers abruptly to very short foot with equally short, acute toes; corona extends ca. 30% along ventral surface; retrocerebral sac (posterior to brain) round, ductless, encloses eyespot and red pigment granules; trophi cardate; rami lyrate with thin lunate extensions on margins; fulcrum a subsquare plate; unci with single long ventral tooth and smaller accessory, joined by weblike plate; manubria with large, crescentic anterior branch; epipharynx of two irregular plates, finely denticulate on inner margins.

Length: 570 µm; toes 32 µm.

Ecology: In permanent acid waters, apparently feeding on cyanobacteria (blue-green algae) (Myers 1933). Single record from humic waters in Tasmania, near L. Garcia on the west coast, 17.0°C, pH 3.1, 80.6 µS cm⁻¹, 0.6 NTU.

Literature: Koste *et al.* (1988).

Lindia torulosa Dujardin

FIG. 4:4

Lindia torulosa Dujardin, 1841, p. 653, Fig. 22.2

Type locality: (France).

Holotype: Not designated.

Description: Body elongate, fusiform to vermiform, transparent; cuticle thin, very flexible; adult animal tinged yellow to orange-red; transverse folds distinct anteriorly, many partly telescopic annular rings posteriorly in creeping animal; abdomen tapers to rounded lobe of tail; foot indistinctly two-segmented; foot-glands small bulbs in terminal segment; toes small, cylindrical, terminate in minute tubules; mastax specialized virgate, with lyrate rami; alulae well-developed; fulcrum a triangular plate; unci with three teeth, first or ventral most developed; lamellary web unites teeth; manubria with crescentic ventral and straight median branch; epipharynx two bent rods behind mouth, with two rhomboidal lamellae from external angles of which 12–15 thin ribs radiate; small brain with red eyespot; retrocerebral sac brown to black; oesophagus, long, ringed; stomach and intestine not separate, often filled with *Oscillatoria* fragments.

Length: 250–600 µm, toes to 11 µm, trophi 26–32 µm, male to 175 µm.

Ecology: Cosmopolitan in still and flowing waters; mass developments in *Oscillatoria* blooms; single record from Sheepwash Billabong, Yea, Victoria, 11.0°C, pH 7.2, DO 6.1 mg l⁻¹, 170 µS cm⁻¹, 17 NTU.

Literature: Koste (1978).

Lindia truncata (Jennings)

FIG. 4:5

Notommata truncata Jennings, 1894, p. 16, Figs 10, 11.
Lindia truncata after Harring & Myers, 1922, p. 626,
 Fig. 54:1, 2.

Type locality: Lake St Clair, Michigan, in bottom vegetation.

Holotype: Not designated.

Description: Elongate fusiform body, with annulate transverse folds, tapers to rounded tail; two-segmented foot with short, conical toes; body orange-brown to red coloured; retrocerebral sac dark red to red-brown; cerebral eye carmine red; mastax with two large salivary glands pushing posterior ends of manubria outward; rami lyrate with large alulae and long right-angled dorsal extension supporting rami; fulcrum slender, tapering; unci with three teeth united by lamellary web; ventral branch of manubrium crescentic, dorsal branch short, forms anterior margin of broad lamella projecting dorsally; epipharynx two hammer-like pieces behind mouth; brain large and elongate, posteriorly with hemispherical heavily red-pigmented retrocerebral sac enclosing eye-spot.

Length: 200–512 μm , toe 8–15 μm , trophi 30–43 μm long, to 50 μm wide (fulcrum 9 μm , manubria 25 μm , rami 16 μm); epipharynx width 19 μm ; subitaneous egg 90 \times 60 μm .

Ecology: Europe, N. America, E. Asia in *Rivularia* and *Gleotrichia* colonies, occasionally in periphyton on submerged macrophytes. Two records: Yarnup Swamp, W.A. and Scotts Peak, near L. Pedder, Tas. 14.0°C, pH 6.2, 75–1600 $\mu\text{S cm}^{-1}$.

Literature: Kostic *et al.* (1983), Kostic & Shiel (1987).

Incertae sedis

A. rotifer identified as *Russelletia* (sic) *parrotti* Russell ? was listed from Myall Lake, ca. 80 km north of Newcastle, by Sudzuki & Timms (1977). No description or figures were provided. If this is the rotifer described by Russell (1947), it was ascribed to the genus *Lindia*, now placed in the family Lindiidae, not *Rousseletia* (Notommatidae).

Lindia parrotti Russell

Lindia parrotti Russell, 1947, p. 403.

Type locality: Victoria Lake, Christchurch, N.Z.

Holotype: Canterbury Museum, Christchurch.

Description: Elongate, slender body tapering gently to foot; no distinct separation between head and abdomen; annulation obvious in contracted animal; foot rudimentary, no tail; toes short; single dorsal antennae on papilla; lateral antennae not described; corona weak, oblique, extends ventrally to retractile

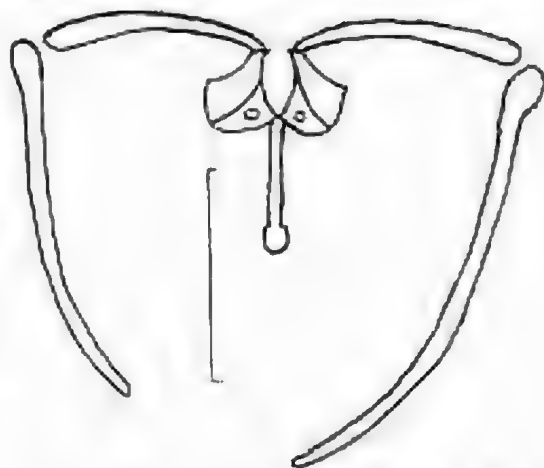


Fig. 5 Trophi of *Lindia parrotti* Russell, 1947 as figured by Russell. Scale line 5 μm .

chin; mastax cardate, small; fulcrum long, narrow, terminates in circular plate; rami lyrate, not denticulate; unci with four teeth (three rudimentary, lamellate); manubria long, slender, curved, expanded proximally at junction with unci; ?no epipharynx; ?no retrocerebral organ; foot glands indistinct.

Length 80–100 μm ; width 27–35 μm ; manubrium 7–9 μm ; uncus 5 μm ; fulcrum 3 μm ; subitaneous egg 45 \times 25 μm .

Ecology: Described from Victoria Lake, Christchurch, N.Z. 18–24°C, pH 8.5–10. Record from Myall Lake needs verification. Occurrence with *Brachionus plicatilis* and other halophile rotifers and microcrustaceans suggests that the Myall Lake species is a halophile.

Literature: Sudzuki & Timms (1977).

Comment: Russell provided no figure of this species, and the trophi as figured (Fig. 5) are inadequate, however the description appears valid. No authority is given by Sudzuki & Timms for the relocation of *L. parrotti* to the notommatid genus *Rousseletia* Harring. Russell described the trophi as cardate (vs. virgate trophi in *Rousseletia*); other differences in trophi morphology separate the genera. We regard the Myall Lake record as *incertae sedis*.

Acknowledgments

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MORPHOLOGY AND BIOLOGY OF THE AUSTRALIAN TREE FROG *LITORIA PEARSONIANA* (COPLAND) (ANURA: HYLIDAE)

BY KEITH R. McDONALD*† & MARGARET DAVIES†

Summary

Litoria pearsoniana (Copland) is a small, polymorphic tree frog found in northeastern NSW and southeastern Qld at elevated altitudes. Morphometric data, colour variation and osteological data are provided together with observations on large winter aggregations of the species, temperature regulation and behaviour. The call and tadpole are described and a possible decline in populations is reported.

KEY WORDS: *Litoria pearsoniana*, tree frog, morphology, biology, advertisement call, osteology, larval development, winter hibernaculum, distribution.

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Litoria pearsoniana (Copland) is a small, polymorphic tree frog found in northeastern NSW and southeastern Qld at elevated altitudes. Morphometric data, colour variation and osteological data are provided together with observations on large winter aggregations of the species, temperature regulation and behaviour. The call and tadpole are described and a possible decline in populations is reported.

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Introduction

Litoria pearsoniana (Copland) is a small hylid frog occurring on the eastern seaboard of Australia. It is closely related to *Litoria citropa* (Duméril & Bibron), *L. subglandulosa* Tyler & Anstis, *L. piperata* Tyler & Davies and *L. phyllochroa* (Günther) with which it forms the *L. citropa* species group of Tyler & Davies (1978).

In the original description Copland (1960) compared *L. pearsoniana* with *L. gracilentia*, but not with more closely allied species. Moore (1961), Cogger (1975) and Cogger, Cameron & Cogger (1983) considered it to be a synonym of *L. phyllochroa* although these latter authors did not justify their conclusion. Frost (1985) recognised the species on the basis of chromosome data presented by King (1980) and differences in call indicated by Barker & Grigg (1977).

The name *L. barringtonensis* (Copland) has been applied by Ingram & Covacevich (1981) and Czechura (1983) to species here recognised as *L. pearsoniana*. However, none of these authors provided justification for the name change. The types of *L. phyllochroa barringtonensis* are subadult, and a conclusion as to their status was considered to be impossible by Tyler & Davies (1985) in the absence of topotypic material reliably identified as *L. pearsoniana*, *L. phyllochroa* or *L. piperata*.

Few data have been published on the biology and habitat preferences of *L. pearsoniana* other than those provided in the description by Copland (1960), Straughan (1966)¹ and Barker & Grigg (1977), despite the species' abundance throughout its range during this study.

Here we report data on the morphology, habitat, biology and distribution of the species, collected during Queensland National Parks and Wildlife Surveys within the Moreton region of Queensland, and in particular the Kilcoy Shire (McEvoy *et al.* 1979).

Materials and methods

The specimens reported here are lodged in the following collections: Queensland Museum, Brisbane (QM); South Australian Museum, Adelaide (SAM); University of Adelaide Zoology Department (UAZ); Queensland National Parks and Wildlife Service (QNPWS).

Animals were measured with dial calipers measuring to .01 mm.

Methods of measurement of adults follow Tyler (1968). The following measurements were taken: snout-vent length (S-V); tibia length (TL); head width (HW); head length (HL); eye to naris distance (E-N); internarial span (IN). Measurements are expressed in mm, as mean (\bar{x}) \pm standard deviation.

Larvae were staged according to Gosner (1960). The following measurements (in mm) were taken using dial calipers measuring to .05 mm or an eyepiece micrometer: total length (TL), body length (BL), maximum body width (MBW), body width at eyes (EBW), maximum body depth (BD), snout to eye (SE), snout to naris (SN), eye to naris (EN), snout to spiracular opening (SS), internarial

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¹ Straughan, I. R. An analysis of species recognition and species isolation in certain Queensland frogs. Ph.D. thesis, University of Qld. Unpubl.

distance (IN), interorbital distance (EE), width of outer eye surface (OE), eye diameter (E), pupil diameter (P), narial diameters (ND), transverse oral disc diameter (TDD), basal tail muscle height (BTMH), basal tail muscle width (BTMW), maximum dorsal fin height (DF), maximum ventral fin height (VF), distance from maximum dorsal fin height to body terminus (BDF), tail muscle height at maximum dorsal fin height (TMD), distance from maximum ventral fin height to body terminus (BVF), tail muscle height at maximum ventral fin height (TMV).

Calls were recorded on a Uher 4000 Report portable reel-to-reel tape recorder at a tape speed of 19 cm/sec and a Gramplan DP₄ microphone. Calls were analysed on a DSP 5000 digital Sona-Graph (Kay Elemetrics) with playback on a Revox B7711 stereo tape recorder. Frequency responses of all audio-electronic components are close to linear with the relevant frequency range (1000–5000 KHz). The built-in set up No. 10 was used for analysis on the Sona-Graph.

Classification of vegetation follows Webb (1959). Observations on aggregating frogs were made from August 1976–September 1978. Cloacal temperatures were taken with a Schultheis rapid reading thermometer. Specimens were handled by the hind limbs with a gloved hand to minimize heat transfer. Humidity was determined using a Zeal hygrometer at the opening of the crack occupied by overwintering frogs, whilst air, water and

microhabitat temperatures were measured to the nearest 0.2°C using Schultheis thermometers. Thermometers were calibrated regularly.

Data were analysed using two-tailed Student *t*-test and regression equations.

Illustrations were drawn using a Wild M8 stereo dissecting microscope and an attached camera lucida.

Results

Litoria pearsoniana (Copland, 1961)

FIGS 1–3, 7–12

Hyla pearsoni Copland, 1960 p. 154

Hyla pearsoniana Copland, 1961 p. 168

Litoria pearsoni: Tyler 1971 p. 354

Litoria pearsoniana: Barker & Grigg 1977 p. 56

Litoria barringtonensis: Ingram & Covacevich 1981 p. 299

Definition: Small green tree frogs (♂♂ 24–29 mm, ♀♀ 30–37 mm) with well-developed lateral stripe from naris to flank, brown tympanum, large finger and toe discs, basally webbed fingers, extensively webbed toes, slightly developed submental gland.

External morphology

Only variations from the original description of Copland (1960) are provided here.

S–V of a sample of 20 adult males from the Conondale Ranges ranged from 24.4–29.1 mm (\bar{x} = 23.2 ± 1.3) and S–V of 20 gravid females ranged from 30.5–35.8 mm (\bar{x} = 32.1 ± 1.6). The largest *L. pearsoniana* examined was a female of 37.1 mm S–V.

The head is deep, flattened dorsally, rounded in dorsal view and broader than long (HL/HW, females 0.89–1.00, \bar{x} = 0.95 ± 0.03; males 0.92–0.98, \bar{x} = 0.95 ± 0.02). Eye to naris distance is consistently greater than interocular span (E–N/IN, females 1.24–1.52, \bar{x} = 1.41 ± 0.08; males 1.22–1.52, \bar{x} = 1.38 ± 0.09).

The legs are moderately long (TL/S–V, females 0.49–0.56, \bar{x} = 0.53 ± 0.22; males 0.51–0.55, \bar{x} = 0.53 ± 0.01). Webbing between the toes is extensive (Fig. 1), reaching the subarticular tubercle at the base of the penultimate phalanx of toe IV. The fingers are long and slender with large terminal discs and a trace of webbing between the second and third and third and fourth fingers (Fig. 1). A rudimentary submental gland is present.

The colour is highly variable within the species. The dorsum of live adults varies. The following colours were observed: dark brown, brown with green suffusions, yellowish brown with green suffusions, brown and green and completely green, all with or without black spots or reticulations. A brown canthal stripe extends from the naris through

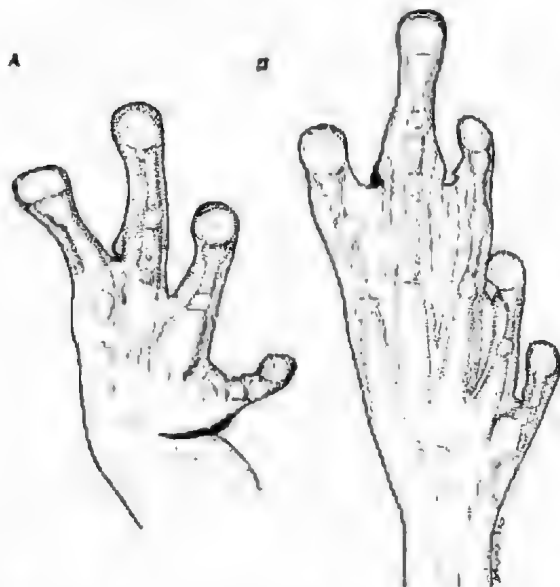


Fig. 1. A, Palmar view of hand and B, plantar view of foot of *Litoria pearsoniana* (UAZ reference collection).



Fig. 2. *Litoria pearsoniana* in life (Conondale Ranges).

the eye and tympanum along the flank to the mid-body (Fig. 2). It is barely discernible in brown specimens.

The anterior and posterior surfaces of the hindlimbs vary from yellowish tan to brick red and can change in an individual over a short period of time. The tympanum is brown merging with the canthal stripe in all the specimens examined. A white upper lip stripe is sometimes present. The iris is golden or bronze. The ventral surface is cream.

Coloration can vary seasonally. Individuals examined from a winter hibernaculum had all of the dorsal colour variation described above. During September when the winter aggregation in the hibernaculum was breaking up, some individuals were brown anteriorly and predominantly mottled green on the posterior half of the dorsal surface and on the legs. In January, these dual coloured frogs were not in evidence. Individuals were either green or brown mottled with green, with all degrees of these colorations occurring. An individual can thus vary from brown to brown and green mottling to predominantly green. Black spotting occurs on both green and brown animals with similar frequency.

Osteology

(based on UAZ A1034, an adult male, S-V 25.3 mm)

Skull moderately ossified (Fig. 3). Sphenethmoid well-ossified extending between nasals dorsally and between vomers ventrally, overlain dorsolaterally by nasals. Prootic and exoccipital completely fused; exoccipitals separated dorsomedially by calcified plate extending anteriorly to form posterior margin of frontoparietal fontanelle. Crista parotica moderately short and stocky, overlain laterally by poorly expanded otic ramus of squamosal. Frontoparietal fontanelle moderately extensive, circular, bordered laterally by poorly ossified frontoparietals which edge about 60% of length of orbit. Anterior margin of frontoparietal fontanelle formed by sphenethmoid at level of anterior 25% of orbit. Posterior margin at level of prootic. Nasals moderately broad, moderately separated medially with acutely tapering maxillary process not articulating with very poorly developed preorbital process of deep partes faciales of maxillae.

Palatines moderately long, moderately slender and acuminate, terminating on sphenethmoid

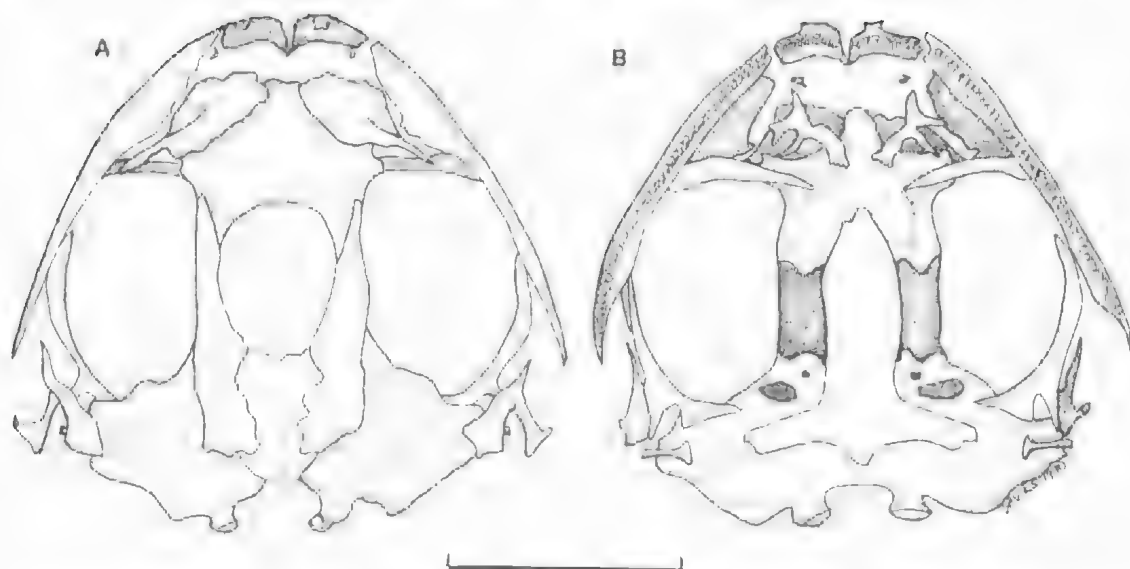


Fig. 3. A, Dorsal and B, ventral views of the skull of *Litorea pearsoniana* (U.A.Z. A1034). Scale bar = 5 mm.

between level of dentigerous and posterior alary processes of vomers. Parasphenoid robust with broad cultriform process terminating behind level of palatines. Alary processes moderately slender, short, angled posterolaterally, not overlain by medial rami of pterygoid.

Pterygoid moderately robust; anterior ramus in contact with maxilla about $\frac{1}{2}$ -way along length of orbit; posterior ramus short and acuminate; medial ramus expanded distally, in bony contact with prootic. Quadratojugal reduced to base of squamosal. Squamosals moderately robust with short, acuminate zygomatic ramus and poorly expanded otic ramus. Maxilla and premaxilla dentate. Alary processes of premaxillae robust, vertical. Palatine processes of premaxillae short, inclined posteromedially.

Vomers slender, reduced medially (Fig. 3). Short dentigerous processes inclined slightly to midline. Bony columella present. Processus coronoideus of mandible hooked. Pectoral girdle arciferous and robust. Omosternum and xiphisternum present; clavicles slender, curved, minimally separated medially; coracoids robust, moderately separated medially. Bicapitate scapula equal in length to clavicle. Suprascapula about $\frac{3}{4}$ ossified. Well-developed humeral crest.

Eight procoelous non-imbricate presacral vertebrae. Relative widths of transverse processes III > IV = II > V > VI = VII = VIII. Sacral diapophyses moderately expanded; ilia extend

anteriorly to anterior extremity; urostyle bicondylar with dorsal crest extending about $\frac{2}{3}$ its length.

Pubis calcified; poorly developed ilial crest. Dorsal prominence moderately developed, more lateral than superior; dorsal protuberance lateral.

Phalangeal formula of hand 3, 3, 4, 4. Terminal phalanges clawed; well-developed bony prepollex. Radials, os centrale postaxiale and os centrale preaxiale present in carpus.

Phalangeal formula of foot 3, 3, 4, 5, 4; small bony prehallux. Os distale tarsale 1, 2, and 3 present in tarsus.

Variation: A further seven specimens were examined. Variation occurs in the degree of ossification of the sphenethmoid which can extend between and anteriorly to the nasals. The anterolateral edge of the nasal can be in contact with the dorsal edge of the pars facialis. The anterior extremities of the ilia extend about $\frac{1}{2}$ -way along the length of the sacral diapophyseal expansion.

Comparison with other species

L. pearsoniana is a member of the *L. citropa* species group of Tyler & Davies (1978, 1985) comprising *L. citropa*, *L. subglandulosa*, *L. phyllochroa*, *L. pearsoniana* and *L. piperata*.

L. pearsoniana differs from *L. citropa* and *L. subglandulosa* by its smaller size and by the poorly

developed submental gland. From *L. pipertata*, *L. pearsoniana* differs by the presence of a conspicuous canthal stripe (faint and narrow in *L. pipertata*) and by the absence of a conspicuous anteromedial flange on the otic ramus of the squamosal and greater ossification of the vomers.

L. pearsoniana can be separated from *L. phyllochroa* by having a brown tympanum (green in *L. phyllochroa*).

Key to members of the *Litoria citropa* species group

1. Submental gland not prominent.....3
Submental gland prominent.....2
2. Tympanum distinct.....*L. citropa*
Tympanum indistinct.....*L. subglandulosa*
3. Canthal stripe prominent.....5
Canthal stripe indistinct.....*L. pipertata*
4. Tympanum brown.....*L. pearsoniana*
Tympanum green.....*L. phyllochroa*

Habitat

Specimens have been observed in rocky mountain streams in closed forest (= rainforest), closed forest with emergent *Eucalyptus* forest, or in thickly vegetated streams adjacent to closed forest, in elevated areas of southeast Queensland, and northeast New South Wales.

Adult behaviour

The macrohabitat was complex notophyll vine forest and sclerophyll vine forest of Webb (1959).

In spring and summer adult male frogs were collected during the day under logs, rocks, rotting leaf litter and moist cavities in the soil immediately adjacent to the water edge. At night males were

observed calling from rocks, ferns, grass, dead branches and leaf litter in or near streams. The greatest height above water was approx. 1 m. Dry bulb temperatures taken near calling males were 13.9°C–24.8°C. Calling increased on warm nights during and immediately after rain.

In winter *L. pearsoniana* forms aggregations under rocks, in cracks in rocks, in cracks in bridge girders and also in cracks behind waterfalls (G. Czechura pers. comm.). Males and females aggregate together and an aggregation located in cracks between bearers on a bridge at the Kilcoy Creek study site (Fig. 4) was observed in the winters of 1976–1978. A sample of 139 taken on 7 September 1976 had a sex ratio of 1 ♀:4.79 ♂.

The cracks between the bridge bearers were 0.6–1.0 cm wide in the front and tapered backwards (Fig. 5). Not all cracks were occupied. All narrow openings other than those in the front of cracks were sealed off with mud from old wasps nests and silt seepage from the top of the bridge. Within the occupied cracks the mud had been pushed to the sides and backs of the cracks.

Each frog adopted a pose similar to that of *L. chloris* illustrated by Tyler (1989 plate 35). All were close together in groups in the cracks and all faced toward the opening. Dorsal and ventral surfaces were in contact with the wood surfaces. The eyes were partially or completely closed when examined *in situ* by torch light. Frogs were very lethargic when disturbed or handled.

In early August 1978, 188 frogs were located in the heater cracks. The aggregation had formed during May and broke up in September. It partially disbanded in August 1978 when weather conditions were overcast with light rain, but it reformed 24 hrs later when cool, fine weather predominated. The only record of the break up of the aggregation during the three years of the study was on 7 September 1977 (air temperature 13.9°C at 8.50 p.m. after the first spring light rain) when some breeding commenced; males were calling at intervals and some females spawned. However most males were not giving the complete diphasic call (Straughan 1966¹). The aggregation had only partially broken up at this stage but by 7 October 1977 it had completely dispersed and frogs were located during the day in decaying vegetation and under rocks and logs on the water edge.

Relative humidity was high during winter, and readings from close to the cracks during a typical 24 hr period in June 1978 together with ambient temperatures in the cracks, in the water and in the outside air are shown in Fig. 6.

There was no significant difference in body temperature between the sexes ($t = 1.7094$, $df = 86$, $0.05 < p < 0.01$), but the body temperatures



Fig. 4. Bridge girder over Kilcoy Creek, Conondale Ranges. The hibernaculum of *Litoria pearsoniana* was located in the arrowed crack.

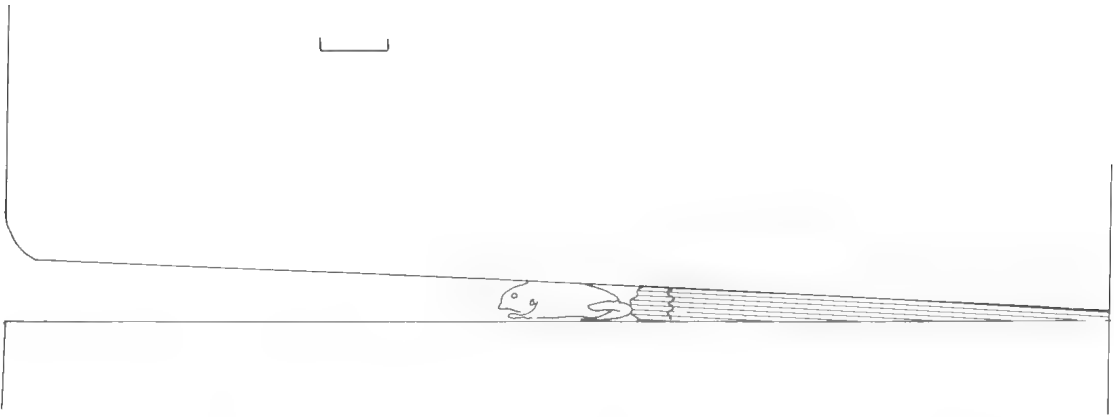


Fig. 5. Dimensions of the crack occupied by a hibernaculum of *Litoria pearsoniana*. Scale bar = 1 cm.

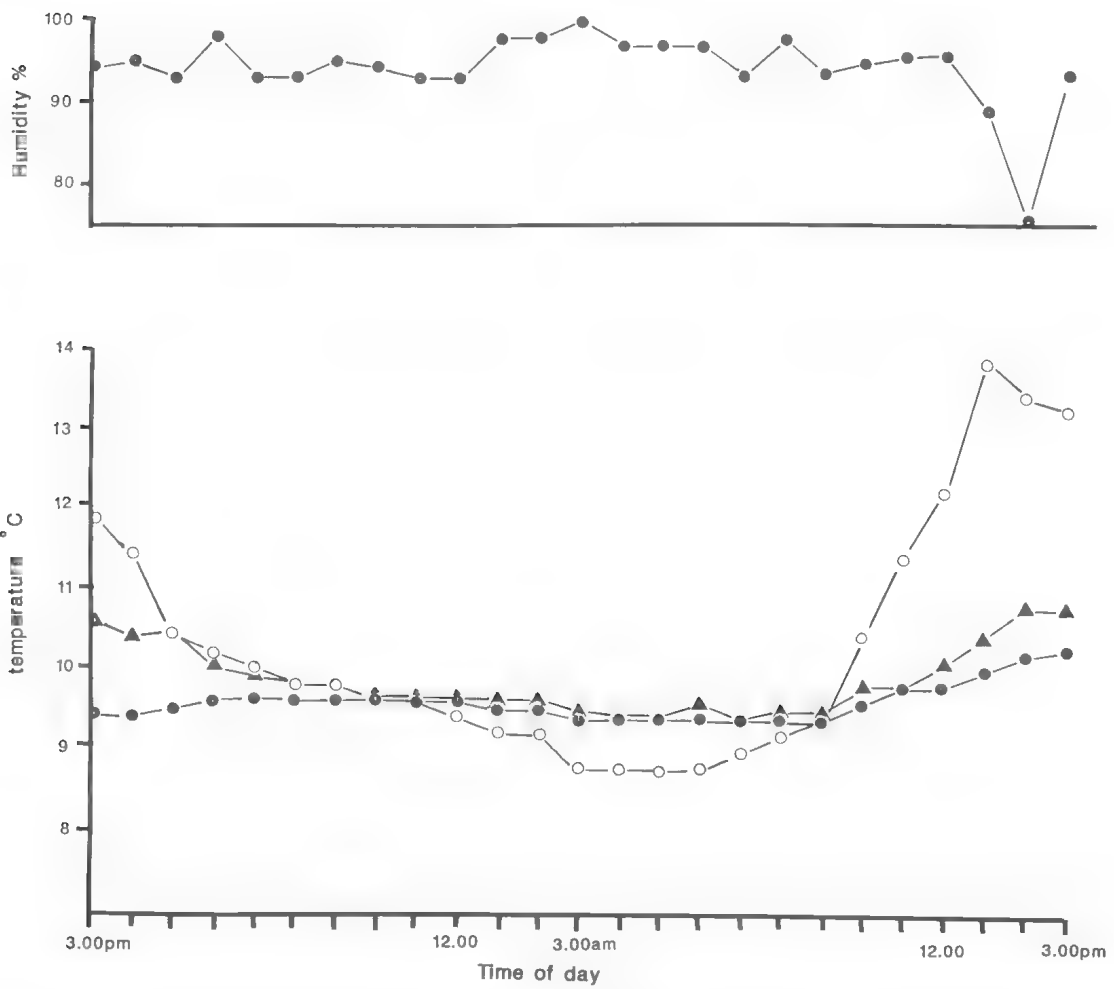


Fig. 6. Relative humidity in the hibernaculum over a 24 hr period in June 1978. Ambient temperature in the crack (closed circle) in the outside air (open circle) and in the water of the stream (triangle) over a 24 hour period in June 1978.

differed between winter and summer ($t = 71.023$, $df = 86$, $p < 0.005$).

Cloacal temperatures of a sample of frogs ($N = 47$, $\bar{x} = 10.12 \pm 0.74^\circ\text{C}$) and of ambient air within the cracks and within 5 cm of each frog on 27 June and 26 July 1978 are depicted in Fig. 7A. These winter body temperatures were significantly different from ambient temperature ($t = 4.758$, $df = 45$, $p < 0.005$), the body temperatures being higher on average. There is no significant correlation between body temperature and ambient temperature ($N = 47$, $df = 45$, $r = -0.08864$, $p > 0.10$). Summer body temperatures taken on 17 January 1978 and 23 January 1978 also were significantly different from ambient temperature ($t = 7.82$, $df = 39$, $p < 0.005$). Cloacal temperatures of breeding frogs in summer ($N = 41$, $\bar{x} = 22.74^\circ\text{C} \pm 0.93$) and ambient air temperature within 3 cm of each frog are shown in Fig. 7B. Again there is no significant correlation between body temperature and ambient temperature ($N = 41$, $df = 39$, $r = -0.18016$, $p > 0.10$).

Temperatures in two cracks lacking frogs did not differ from those in cracks with frogs, but the unoccupied cracks were not true controls as they were of differing dimensions and were not occupied by an equivalent non-living mass similar to the bulk of frogs in the other cracks.

Breeding biology

Males call consistently from early September to February with some spasmodic calling in March and April. Peaks of calling were observed to occur from October to early February, coinciding with the summer rains and the major breeding season.

The call is a diphasic three-note call and can be likened to "Weeek Kuk Kuk". It lasts from 0.8–1.8 seconds (Straughan 1966¹). The waveform display of an advertisement call taken in the Jimna State Forest at Marumba Creek is shown in Fig. 8. Air temperature at the calling site was 18°C . Call parameters are shown in Table 1. This recording was from a single male sitting on a rock above water, and may not be representative of the calls made in a chorus.

Calling can vary in several ways. A very slow version of the first part of the advertisement call is sometimes heard early in the evening. Sometimes the first part of the call is made by one male and answered by a second by completing the sequence. The duration of these calls and parts of calls is quite variable.

Another call, consisting of the last two notes of the full call repeated several times, was noted in a general chorus recording. We cannot comment further upon the call data in the absence of appropriate temperature measurements.

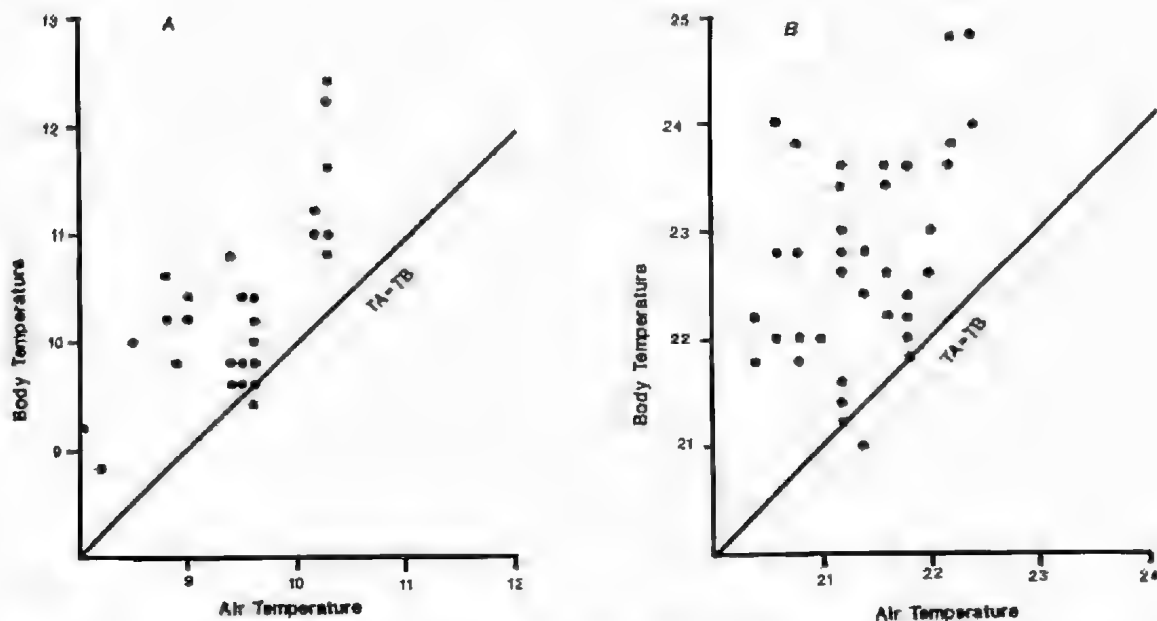


Fig. 7. A. Cloacal temperatures of *Litoria pearsoniana* and ambient temperatures in the crack on 26 June and 27 July 1978. B. Cloacal temperatures of breeding *Litoria pearsoniana* and ambient temperatures in summer.

TABLE 1. Characteristics of the biphasic call of *Litoria pearsoniana* taken at Marumba Creek, Jimna State Forest, Qld. Air dry temperature at calling site was 18°C.

	Duration	No. of Pulses	Pulse repetition rate (pulses/sec)	Dominant Frequency (Hz)
Complete call	871.9	—	—	—
Introductory note	262.5	c. 377 ¹	432.1	2280, 2680, 3080 ²
First repeated note	84.4	6	67.4	1840
Second repeated note	78.1	6	73.6	1840

¹ Back calculated from note duration and the pulse repetition rate measured from 20 pulses and pulse intervals taken from near the middle of the note.

² Three peaks of equal intensity probably representing emphasized size band frequencies generated by the modulating frequency of c. 400 Hz (the pulse repetition rate of the call).

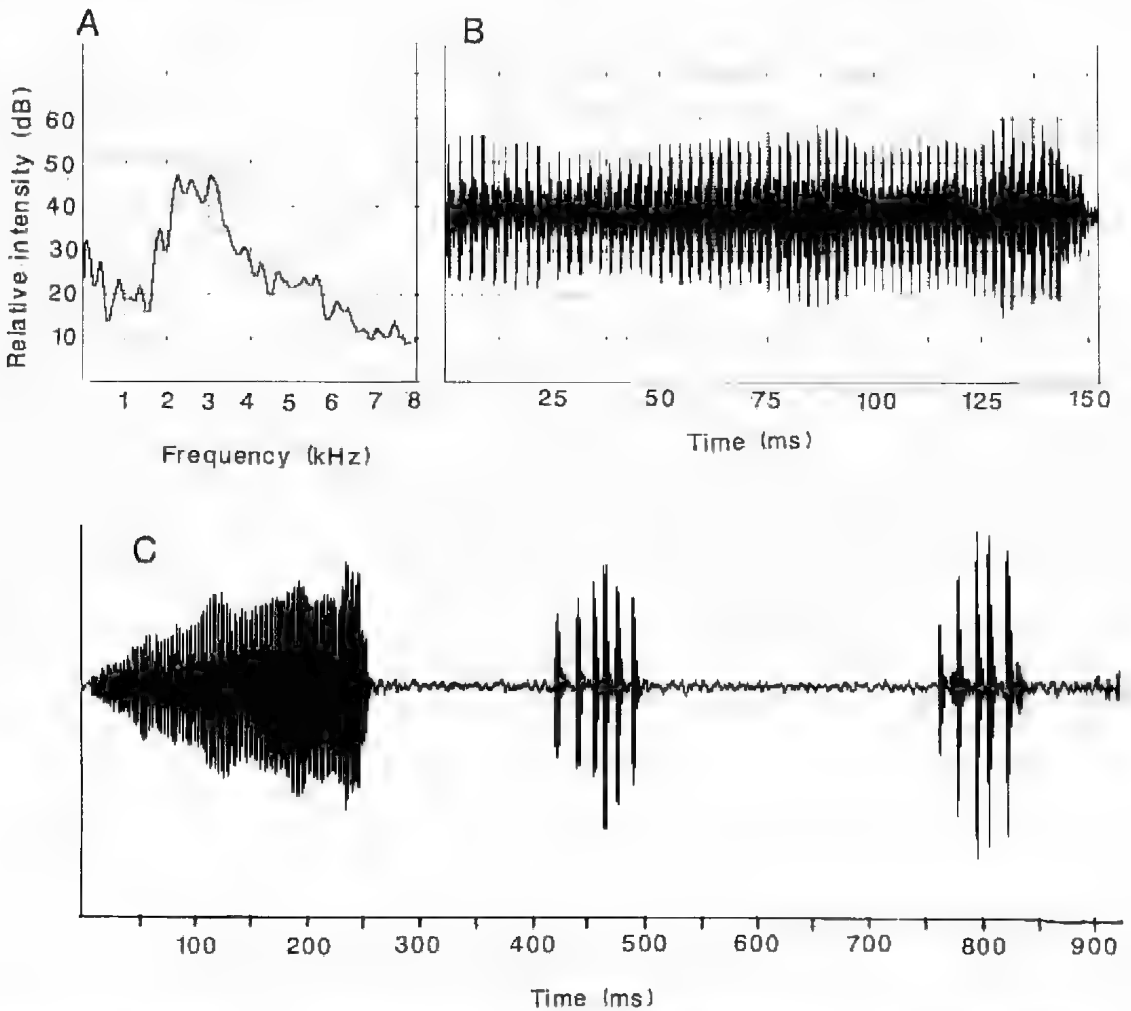


Fig. 8. Waveform display of a calling male *Litoria pearsoniana* at Marumba Creek in the Conondale Ranges. Air temperature at the calling site was 18°C. A = Power spectrum of the introductory note; B = Last segment of introductory note, showing pulses; C = Complete call.

Gravid females were found in the winter hibernaculum from June to August. Ova were at various stages of development with some females having the body cavity fully occupied by eggs.

Litoria pearsoniana was the first species of frog to spawn of the eight species (*Adelotus brevis*, *Mixophyes fasciolatus*, *M. iteratus*, *Rheobatrachus silus*, *Tandactylus diurnus*, *Litoria chloris* and *L. lesueuri*) at the study site in Kilcoy Creek. A female which spawned in the field on 15 November 1978 and retained in the laboratory possessed large pigmented ova on 7 December 1978 suggesting a capacity to breed more than once in a season.

Axillary amplexus takes place adjacent to pools connected to or separated from creeks. After amplexus is achieved at or near the male's calling site, the female moves to the water and adopts a position in which about $\frac{1}{3}$ of her abdomen and $\frac{1}{4}$ of that of the male is submerged in the water. When spawning, the female takes a semi-upright position, clasping leaves, rocks or twigs. Spawning usually takes place at night, but has been observed at midday on an overcast day in a shady area of the creek.

Eggs are deposited in still, shallow pools adjacent to, or connected with, the main stream. The greatest depth of water in which ova were deposited was 35 mm. Over the period 1976–1978, spawning commenced in early September, although on one occasion (8 August 1978) breeding occurred earlier in unusually warm conditions with an overcast day and light rain. When cooler weather returned 24 hrs later, the winter hibernaculum reformed until September. The eggs laid on 8 August 1978 were at stage 15 on 17 August 1978 and had not hatched.

Eggs are 1.1–1.3 mm in diameter and are individually capsulated in a clear jelly 3.0–3.5 mm in diameter. They are attached in a mass to twigs, rocks, leaves and vegetation. Eggs have a dark brown animal pole and an off-white vegetal pole. Macroscopically they appear to be black. Silt settles on the jelly capsule in one to two days giving it a grey or brown appearance and concealing the developing embryo. Eggs are laid 5–8 at a time, with occasional groups of up to 12, and can be along twigs and rock surfaces or in clumps on the bottom of a pool. The longest row of eggs measured was 24 cm. Eggs are usually clumped together rather than strung out over such long distances. Spawn clumps comprise 363–732 eggs ($\bar{x} = 445$, $n = 10$).

Larvae

Initial development is rapid, neurulation occurring in 2–3 days with hatching occurring 3–5 days after spawning in late September. The eggs hatch at stage 19.

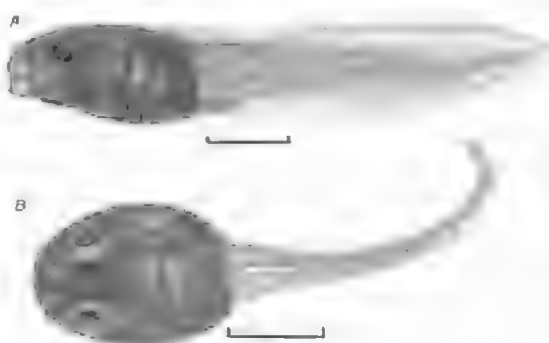


Fig. 9. A, Lateral and B, dorsal views of a tadpole of *Litoria pearsoniana* at Stage 37. Scale bar = 5 mm.

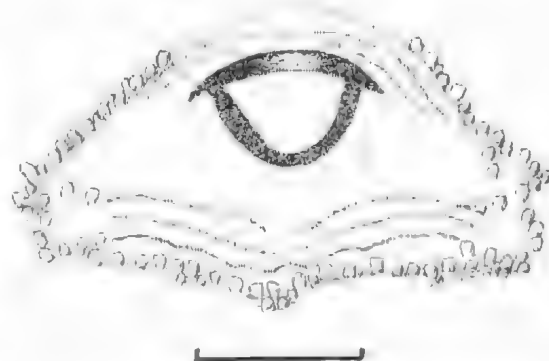


Fig. 10. Oral disc of a tadpole of *Litoria pearsoniana*, Stage 37. Scale bar = 1 mm.

The following description is of a tadpole at stage 37. Body broader than deep with greatest breadth posterior to eyes (Fig. 9). Mouth ventral (Fig. 10) with two upper and three lower rows of labial teeth. The second upper and first lower row have a median gap. Labial papillae surround lateral and posterior margins of mouth.

Dorsal surface of body brown. In later stages of development some specimens have dark spots dorsally.

Spiracle sinistral and ventrolateral (Fig. 10). Anal aperture dextral, opening adjacent to ventral fin. Tail moderately thick, deepest in anterior $\frac{1}{3}$. Tip rounded. Neuromasts of lateral line lightly blotched with brown. Fins transparent with clusters of melanophores anteriorly and superiorly. Greatest depth of fin is posteriorly. Ventral surface of body unpigmented. A light golden appearance is characteristic of early stages (i.e. 25–28). Metamorphosis of tadpoles reared at ambient temperature from spawn collected on 27 September

TABLE 2. Measurements (in mm) of single larvae of *Litoria pearsoniana*. See text for abbreviations.

Gosner stage	25	37	39	40	41	42
TL	11.52	30.2	25.6	22.6	30.7	27.2
MBW	3.92	7.8	6.16	5.76	8.3	6.0
EBW	3.6	6.2	5.84	5.60	6.9	5.6
P	0.24	0.32	0.48	1.44	0.48	0.56
OE	0.6	1.76	1.76	2.4	1.6	1.6
IN	0.92	1.2	0.96	1.12	1.32	0.96
SE	1.68	2.16	2.08	2.88	2.96	1.68
EN	0.68	1.04	0.96	1.12	1.48	1.28
RTM	0.96	3.52	2.56	3.44	3.6	2.4
DFH	0.96	3.24	1.52	1.52	2.24	1.6
BL	4.44	10.2	8.4	8.12	11.6	9.12
BD	2.32	6.4	3.68	4.4	4.5	3.84
E	0.48	1.28	2.0	1.36	1.36	1.6
EE	1.12	1.44	3.76	2.56	2.8	1.92
ND	1.6×0.4	0.32×0.32	1.6×0.4	0.32×0.24	0.48×0.48	0.24×0.24
SN	0.48	0.96	1.12	1.68	0.88	0.24
SS	3.24	6.64	6.08	6.8	7.8	—
TDD	1.44	2.88	2.56	2.56	3.36	1.44
BTMW	0.72	2.5	1.76	2.56	3.0	2.56
VF	0.72	1.6	1.2	0.64	1.28	1.04
BDF	3.6	12.8	7.84	9.6	8.0	9.6
BVF	3.6	12.8	7.84	9.6	8.0	9.6
TMD	0.4	1.44	1.52	1.12	3.04	1.28
TMV	0.4	1.44	1.52	1.12	3.04	1.28
DVFB	2.28	5.12	3.6	3.44	4.96	3.12

1977 was completed between late December 1977 and early January 1978: a larval life of 2–2½ months.

Mean snout-vent lengths of seven newly-metamorphosed individuals was 9.9 mm (9.3–11.1 mm). Colour was dark brown with a reticulated appearance. No green pigmentation was evident. Newly-metamorphosed individuals were observed in the field in January and February.

Measurements on a developing series of tadpoles are provided in Table 2.

Distribution

Litoria pearsoniana has a distribution in preferred habitat from northeastern N.S.W. (vicinity of Lismore) to the vicinity of Kenilworth, southeast Qld, with an isolated population on Kroombit Tops (Czechura 1986) (Fig. 11). The species is restricted to elevated areas, and has not been located in lower coastal country. Distribution appears to be influenced by the presence of a combination of closed forest or thick vegetation, flowing rocky streams and elevation.



Fig. 11. Distribution of *Litoria pearsoniana* in northern N.S.W. and southeastern Queensland.

Conservation status

At the time of this study (1976–1978), the species was exceptionally abundant (using the criteria of Kirkpatrick & Lavery 1979). However, the species declined at the end of the decade and in December 1983 at the site at which 50 *L. pearsoniana* were collected and checked for colour variation in 1978, only five specimens were seen and heard over a period of 1½ hrs. At this time no confirmed egg masses of *L. pearsoniana* were observed.

Other species of frogs have disappeared from this area including the Gastric brooding frog *Rheobatrachus silus* (Ingram 1983) and the southern day frog *Taudactylus diurnus* (Czechura 1984). We have no further data on abundance of the species and hence are unsure whether the populations have "declined" at other sites along their distribution or of the status of the Conondale Range populations at this time.

Material examined

SAM R17583–5, Warrie N.P., Springbrook; NPWS N15760–2, N15765–7, N15776–81, N17199, N17271–4, N17276, N17278, N17283, N17285–6, N17287–8, N17290–4, N17569–74, N17587, N28004, Conondale N.P., Kilcoy Creek Bridge; N17087, Conondale Ra, Bellthorpe S.F., Sandy Creek; A320, A323, Mt Glorious; A468–471, Twin Falls, Warrie N.P.; A476, Goomoolara Falls, Warrie N.P.; A326, N12012–28, Warrie N.P.; A357, A859–60, Cunningham's Gap N.P.; A352, Giraween N.P.; A758–760, Kondahilla N.P.; N17087, Conondale Ra, Sandy Creek, Bellthorpe S.F.; N17384, 17510, Kundys Hut, Murumba Ck, Jimna S.F.; N17560–3, East Branch, Kilcoy Creek; N17882–4, Murumba Ck, Jimna S.F.; QM J30879, J37645, J40420, J40425, J40428, J40447, Eden Ck Falls, 25 km SE Woodenbong, N.S.W.; J30885, J37637, J40418, J40423–4, Undercliff, N.S.W.; J31478, 11.4 km W Ballina, N.S.W.; J31494, Tweed Plateau, Qld; J35540, Mt Clunie, N.S.W.; J37647–8, J40501, Mackintosh's Rd, nr Woodenbong, N.S.W.; J40419, J40427, Back Creek Rd, Unungah State Forest (20°25'S, 152°42'E); J46935, Snow Ck, Upper Cooper Ck (28°33'S, 153°23'E), UAZ A87, Mt Nebo; A88–9, Warrie N.P., Springbrook; B421, A1034, A1454–5, Conondale Ra.

Discussion

Litoria pearsoniana is closely related to other members of the *L. citropa* species group as defined by Tyler & Davies (1978, 1985). It shares with these species a number of features including a submental gland and the habit of forming winter aggregations, the choice of breeding sites, the method of egg deposition (Tyler & Anstis 1975; Harrison 1922).

Larvae of *L. pearsoniana* show typical hylid characters in the dorsolateral position of the eye and ventrolateral spiracle. However, the gently rounded tail tip is not typical of hylids (Banks *et al.* 1983). The tooth row formula is typical of many Australian hylid tadpoles (Martin & Watson 1971) and similar

to that of *L. citropa* although differing from that species in possessing labial papillae that entirely surround the oral disc. The oral disc of *L. subglandulosa* lacks tooth rows and comprises a funnel of papillae of varying lengths (Tyler & Anstis 1975). Tadpoles of *L. piperata* and *L. phyllochroa* have not been described.

The tadpoles of *L. pearsoniana* have more lotic adaptations in that they are not a high finned nektonic type typical of many Australian hylids (Banks *et al.* 1983).

The call of *L. pearsoniana* is complex and we present the data here to provide a basis for elaboration by other workers.

The observations on overwintering aggregations reported here are the first detailed for an Australian frog species, and suggest that the frogs actively seek appropriate microenvironments in which to overwinter. The full details of site selection remain obscure, but the data indicate that the amplitude of temperature fluctuations and the relative humidity conditions within the microhabitat are important factors. The cracks appear to stabilize both temperature and humidity and the macrohabitat (dense closed forest and associated perennial streams) reduces extreme fluctuations in air temperature and humidity that would be experienced in more open vegetation (Greenslade & Thompson 1981).

Position and posture within the cracks also are important factors in that crowding and maintenance of the limbs against the body reduces exposed surface area and this conserves moisture (Johnson 1971; Tyler 1976, 1989; Heatwole 1963; Heatwole *et al.* 1969).

Body temperatures of inactive frogs in winter were less than 2°C above the temperature in the crack over a 24 hr period. The air within the crack fluctuated through 1°C whilst that outside varied by 5°C. The significant difference between body temperature and ambient air temperature for both summer and winter implies some form of control over body temperature by the frogs.

Populations of species of frog such as *L. pearsoniana* which form winter aggregations can become extremely vulnerable during these periods. Complete or partial destruction of aggregation sites could result in the elimination of a local population whilst destruction of macrohabitat would subject any population remaining to adverse changes in temperature and moisture fluctuations.

The possible decline of the species in the Conondale Ranges is cause for concern as it mirrors declines in other species in that area and elsewhere (Tyler *in press*). Such declines may be indicative of major environmental problems and as such, deserve careful study.

It should be noted that amongst the material examined in this study were five specimens from Barrington Tops, N.S.W. (QM J34236-9, J34246), the type locality of *Litoria phyllochroa barringtonensis*. These specimens have green tympana and are identified as *L. phyllochroa*. However, in the absence of accompanying call data, we are not prepared to comment further on the status of *L. phyllochroa barringtonensis*.

Acknowledgments

S. Crafter, J. S. McEvoy and Dr J. D. Miller are thanked for assistance in the field. Dr G. F. Watson ran the sonagram and analysed the call while G. Czechura, Dr R. S. Seymour and A/Prof. M. J. Tyler provided critical comment for which we are grateful. Patrick Couper is thanked for the loan of material from the Queensland Museum. Lorna Lucas typed the manuscript.

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C. T. MADIGAN'S CONTRIBUTIONS TO GEOLOGY IN SOUTH AND CENTRAL AUSTRALIA

BY C. R. TWIDALE¹, L. W. PARKIN² & E. A. RUDD¹

Summary

He contributed to our early knowledge of the stratigraphy of Fleurieu Peninsula and of the MacDonnell Ranges, but is best known for his investigations of the Simpson Desert, which he named, and particularly of the age and origin of sand ridges or longitudinal dunes. Many of his conclusions have been modified as a result of later research, but his astute observations and imaginative explanations have earned him an honourable place as one of the very great explorer scientists of this State.

KEY WORDS: Madigan, Simpson Desert, sand ridges, Lake Eyre, Fleurieu Peninsula, MacDonnell Ranges, aerial reconnaissance, evolution of dunes.

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Summary

TWIDALE, C. R., PARKIN, L. W. & RUDD, E. A. (1990) C. T. Madigan's contributions to geology in South and central Australia. *Trans. R. Soc. S. Aust.* 114(3) 157-167, 30 November, 1990.

Cecil Madigan (1889-1947) was for many years a Lecturer in Geology in the University of Adelaide. He contributed to our early knowledge of the stratigraphy of Fleurieu Peninsula and of the MacDonnell Ranges, but is best known for his investigations of the Simpson Desert, which he named, and particularly of the age and origin of sand ridges or longitudinal dunes. Many of his conclusions have been modified as a result of later research, but his astute observations and imaginative explanations have earned him an honourable place as one of the very great explorer scientists of this State.

KEY WORDS: Madigan, Simpson Desert, sand ridges, Lake Eyre, Fleurieu Peninsula, MacDonnell Ranges, aerial reconnaissance, evolution of dunes.

Introduction

The year 1989 marked the centenary of the birth of one of the pioneers of Australian geology, C. T. Madigan. Madigan was one of the last of a generation of explorer-scientists who belonged to an heroic age, yet was active recently enough to be survived by many of those who studied under and worked with him. Madigan's contributions to our knowledge of the stratigraphy of the Fleurieu Peninsula and of the MacDonnell Ranges, and of the nature of the sand ridge deserts of central Australia, are reviewed and placed in perspective.

BIOGRAPHICAL SKETCH

Cecil Thomas Madigan (1889-1947) was born at Renmark in the Riverland of South Australia. The son of a struggling irrigation settler associated with the Chaffey brothers, he was one of a family of five (Parkin 1986). The children were still young when their father died on the Kalgoorlie goldfields while attempting to redress the family fortunes. By working as a teacher with the Education Department of South Australia, Madigan's mother contrived not only to rear her family, but also to see them through to a tertiary education. Cecil won a scholarship to the University of Adelaide, taking a Diploma in Mining Engineering, which was later surrendered for a Bachelor of Engineering degree. Madigan was a brilliant student and athlete, and on graduation at the age of twenty-one, in 1910, he was selected as Rhodes Scholar for South Australia. While in England, he was appointed by Douglas Mawson as meteorologist to the Australian Antarctic Expedition and, having arranged deferral

of his Oxford studies, he sailed for the Antarctic in the "Aurora" in 1911. In addition to his meteorological duties, Madigan undertook several exploratory sledging journeys from the base camp at Cape Denison, during one of which he carried out a winter reconnaissance of the ice plateau of Adelie Land, experiencing record conditions of cold and wind. In the summer of 1912-13 Madigan led the Eastern sledging party which traversed the sea-ice and coastline of what was later to be named King George V Land, a journey of some eight hundred kilometres which took two months to complete. This undertaking coincided with Mawson's ill-fated Far Eastern sledging journey during which Ninnis and Mertz both perished, Mawson himself struggling back alone to base camp too late to embark on the relief ship. Madigan was chosen as leader of the group of seven who remained behind for a second year pending the return of Mawson, or, failing his return, to mount a search. In recognition of his contributions to the expedition Madigan was awarded the King's Polar Medal in 1914.

This brief period of Antarctic exploration was crucial to Madigan's later scientific life, for he demonstrated both to himself and to the world at large, his capacity for organisation and survival in the most rigorous conditions. The exhilaration of treading where no one else had trod lay latent for several years but it was to emerge and flower once the unknown landscapes of central Australia were within his reach.

On his return from Antarctica, Madigan's Oxford studies were again interrupted, this time by the First World War. He joined the Royal Engineers, (Guards Division) rising to the rank of Captain in 1916, and served in France where he was twice wounded and twice mentioned in despatches.

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Upon demobilization, Madigan completed his studies at Magdalen College, Oxford, graduating B.A. in 1919 with First Class Honours in Natural Science (Geology). In 1920 he was appointed Assistant Geologist in the Sudan Civil Service where he served for two years. Meanwhile Mawson, who in 1905 had been appointed Lecturer in Geology and Mineralogy in the University of Adelaide, was promoted in 1921 to the Chair and almost immediately offered Madigan the post of Lecturer, an appointment which Madigan held from 1922 until his death some twenty-five years later. Madigan had been awarded an Oxford M.A. in 1922, and in 1933 his geological researches, principally in the MacDonnell Ranges of the Northern Territory, were recognized by the conferral of a D.Sc. from the University of Oxford.

As a teacher Madigan was responsible primarily for Second Year students, conducting classes in most aspects of geology as then embraced in the academic curriculum, and, in addition, teaching one-term units in both mining geology and engineering geology.

Initially his research focussed upon the Fleurieu Peninsula, and can be seen as complementing the work of Howchin, Mawson and others, but in the late twenties his physical and intellectual energies were given greater scope by his journeys into central Australia, where folded and faulted terrains, like the MacDonnell and James ranges, excited his attention, and where the sand ridges of the Simpson Desert became an obsession that was to dominate his later years. Madigan himself later named the Simpson Desert after A. A. Simpson, then President of the South Australian Branch of the Royal Geographical Society of Australasia and personal sponsor of the 1939 ground expedition that traversed the dune field.

His University duties were interrupted by World War II when he was appointed Chief Instructor, with the rank of Lieutenant-Colonel, in the School of Military Field Engineering at Liverpool, N.S.W. (Fig. 1). He retired from the Army in 1943, resuming his duties with the University of Adelaide, and, in particular, seeing to press the results of the 1939 investigation of the Simpson Desert.

So much for the record – but what of the man? Madigan was tall, of impressive physique, handsome, and confident in any society. His student blues for rowing and boxing attest his physical stature and interest in fitness: attributes that stood him in good stead in his Antarctic and central Australian expeditions. While serving on the staff of the University of Adelaide, he took a great interest in student affairs, being involved in the Students' Union and in the Graduates' Association, of which he served as Chairman, 1943–4. He was



(Fig. 1. Lt Col. Madigan, early nineteen forties (Royal Society of South Australia).

instrumental in founding the Tate Society, an interdisciplinary society for natural science students which organized scientific field camps at various centres of interest in South Australia (Fig. 2).

Madigan was awarded many honours and held numerous professional offices, including Fellow of the Geological Society of London; President of the Royal Society of South Australia 1935, and Verec Medallist 1945; President of the Geographical Section of ANZAAS 1937, and a member of the Council of the Royal Geographical Society of Australasia (S.A. Branch) 1939–1946. His community interests included the Legacy Club, which he served as President, and the Boy Scouts' Association in which he attained the high office of Chief Commissioner for South Australia.

Madigan's many and varied activities made him well-known to the South Australian, and indeed to the Australian, public at large. His scientific reputation however rested on his contributions to the unravelling of the stratigraphy of Fleurieu Peninsula and the MacDonnell and associated ranges in central Australia, on his pioneering efforts in aerial reconnaissance and survey, his observations



Fig. 2. Tate Society expedition to caves near Swan Reach on the River Murray, in 1937: left to right: B. Warhust, P. Nairn, B. Barrien, C. T. Madigan, G. D. Aitchison, R. C. Sprigg, with L. W. Parkin front right (A. F. Pilgrim).

of Lake Eyre, and, most widely and enduringly appreciated, his work on the dunefields of inland Australia, particularly the Simpson Desert (Fig. 3).

FLEURIEU PENINSULA

When Madigan entered the South Australian geological scene, the framework of the State's geology had already been established by such distinguished workers as H. Y. L. Brown, R. Lockhart Jack and Walter Howchin. L. K. Ward was active in his capacity as Director of Mines and Government Geologist. Mawson's interests were concentrated in the basement rocks of the Broken Hill and Olary districts and of the northern Flinders, on the stratigraphy of the Flinders Ranges, and on the ancient glacial sediments exposed in various parts of the State.

Madigan was drawn to Fleurieu Peninsula partly because it had been only cursorily examined by previous workers, but also because, being then served by a railway as far as Willunga, it was relatively accessible at a time when motor cars were comparatively rare; in any case, neither Madigan nor the Geology Department possessed one, nor indeed did Madigan ever own either a car or a driver's licence.



Fig. 3. Map showing places and features mentioned in text.

To place Madigan's Fleurieu Peninsula work in the perspective of the time it is necessary to recall that at this stage Howchin had summarized his own work with the publication of "The Geology of South Australia" (1918). Amongst many other observations, Howchin determined the stratigraphic succession of the Mt Lofty Ranges and concluded that the strata lying unconformably above the highly-metamorphosed Inliers exposed in several areas of the Ranges were of Cambrian age, ranging from Lower Cambrian for those units now designated Adelaidean, through to Upper Cambrian for the fossiliferous (Archaeocyathinae) limestones. The 1918 volume includes a cross-section at Sellick Hill, in the north of Fleurieu Peninsula, which provided Madigan with a starting-point for his own investigations. Madigan re-examined this section, describing each unit meticulously, and redrew it using his own revised lithology. He then extended the work along the coast to Cape Jervis and thence to Victor Harbor, running sections wherever rock exposures were adequate and, using the Archaeocyathinae horizon as a marker, traced the succession throughout the area (Madigan 1925).

He compiled a geological map which appeared as a folded coloured plate in this publication. He made the important observation that the greywackes and associated rocks now known as the Kanmantoo Group overlie the Archaeocyathinae Limestone and are therefore Cambrian or younger, whereas Howchin continued to regard them as Precambrian. Madigan obviously had misgivings about the details of his correlations for he soon returned to the area and concentrated particularly upon the scarp of the Willunga Range, establishing the stratigraphical succession from the fossiliferous limestone to the well-identified Sturtian tillite. He constructed a map on a scale of 1 inch to the mile, showing the relationship of the major units. In a paper resulting from this work (Madigan 1927) he drew attention to the anomalous attitude of the sections in which the Proterozoic Adelaide Series overlies the Archaeocyathinae Limestone, and in a discussion of the problem tentatively canvassed the possibilities of disconformities, overthrusting, or overturned folds to account for the dip reversals.

Although Madigan's 1925 paper is entitled "The Geology of the Fleurieu Peninsula, Part I. - The Coast from Sellick's Hill to Victor Harbour" (with the English rather than the officially approved American spelling of "Harbour"), the Willunga Scarp paper and a brief note on annelid trails and borings in beds below the Archaeocyathinae Limestone at Myponga Jetty (Madigan 1926) remain his only further contributions to the area. In a later paper discussing the age of formations on the north coast of Kangaroo Island (Madigan

1928) however, he returned to the structure of Fleurieu Peninsula, referring to his "temerity" in suggesting the possibility of an overturned succession at the Willunga Scarp and, by implication - and incorrectly - reversing the ages of the annelid-bearing beds and coralline limestone he had mapped. Part II of the Fleurieu Peninsula paper seems to have been overtaken by the diversion of Madigan's interest to the Northern Territory, which was in turn stimulated by the aerial reconnaissances he undertook in 1929.

TAKING TO THE AIR

The use of aeroplanes for reconnaissance and photography is as old as the flying machine itself (see e.g. Walker 1951). Aeroplanes were used by both sides during the First World War for general reconnaissance and artillery spotting, as well as for the strafing and bombing of enemy positions. And during the early twenties O.G.S. Crawford and his colleagues in England began to realise the immense possibilities of air photographs for the detection of archaeological sites, for they revealed patterns that are not discernible on the ground. Even before the War, however, in 1909 or thereabouts, Hubert Wilkins (from Mount Bryan, in the Burra district of South Australia) had, rather precariously, taken photographs of parts of southern England perched astride the body of an aeroplane between the cockpit and the propeller, just - but only just - behind the propeller (see Thomas 1962), and in 1913 Sir Henry Welcome, using a box kite as the vehicle for his camera, had obtained air photographs of an archaeological site he was excavating in the Sudan (Crawford 1953).

As previously noted Madigan served on the Western Front during World War I and he must have been aware of the use being made of aircraft for various purposes. He later worked in the Sudan, and may have heard of Welcome's ingenious efforts there. Whatever the background, Madigan pioneered the use of aircraft for scientific reconnaissance and aerial photography in Australia. Using a Westland Wapiti biplane crewed by service personnel, Madigan made nine flights over central Australia in August of 1929. Basically he criss-crossed what he later called the Simpson Desert, and determined that the area contained nothing but desert, and largely dune desert, though he also flew over Lake Eyre and made traverses east and west of Alice Springs in order to view the MacDonnell Ranges (see Madigan 1931). He took overlapping vertical photographs of many parts of the upland, and used the resultant mosaics as base maps on which he later plotted geological information (Madigan 1932a). This is the first recorded

application of aerial photography to geological mapping in Australia.

Flying over the desert Madigan noted the extraordinary regularity and repetition of the sand ridges, likening the view of the dune-fields to "a flat pink disc, ribbed from horizon to horizon by the red sandhills . . ." (Madigan 1930, p. 95). From the air Goyders Lagoon was "... a maze of watercourses, running in all directions in a black setting of polygonum" (Madigan 1930 p. 93). He noted that the Simpson was much more vegetated than, say, the African deserts (Madigan 1930, p. 96). He was able readily to identify spinifex by its "hollow rings, outward-growing masses from which the centre has decayed and disappeared" (Madigan 1930, p. 95). The aerial view was revealing and Madigan's splendid low oblique photographs grace many of his papers and books.

This series of flights confirmed Madigan in his dedication to the unravelling of the geology of central Australia, for all his later work was devoted to problems noted on these aerial traverses. In particular, his intellectual dedication to deserts in general and the sand ridge deserts in particular dates from this series of aerial traverses undertaken in August 1929.

THE MACDONNELL RANGES

Madigan's flights from Alice Springs along both the eastern and western MacDonnell Ranges encouraged him to plan field expeditions to the area. He and Mawson (Mawson & Madigan 1930) had carried out some preliminary geological work, using aboriginal names for the various stratigraphic units they recognised and mapped. Thus "Atunta" is the name of a local tribe, and "Larapintine" is derived from Larapinta, the aboriginal name for the Finke in the James Range. Many of these names, suitably redefined in some instances, have been retained and appear on modern geological maps of the region (Wells *et al.* 1970). In 1930 Madigan spent a month in the field, accompanied by a youthful and then recently graduated E. A. Rudd. His experience with camels in the Sudan in the early nineteen twenties suggested to him a means of traversing and mapping the western MacDonnell Ranges toward the Western Australian border, where the outcrops disappear under sand; and the same means of transport was used in the Simpson Desert crossing (Fig. 4).

This was the first systematic geological survey of the MacDonnell Ranges and Madigan carefully measured sections related to a key horizon, the Heavitree Quartzite. The geological map he compiled depicted the structure and stratigraphy of the MacDonnell Ranges (Madigan 1932a, 1932b).



Fig. 4. Madigan aboard a ship of the desert in central Australia in the nineteen thirties (E. A. Rudd).

The 1930 expedition extended south of the MacDonnell Ranges to the Waterhouse and James ranges, his cross-sections being the first interpretation of the structure of the now important Amadeus Basin (Madigan 1932). The Horn Expedition (Tate & Wall 1897) had noted the anomalous course of the Finke River as it crossed the fold mountain ranges of central Australia and Madigan (1930, 1931) confirmed this observation. He pronounced the Finke and adjacent rivers as of great antiquity, which is correct, and of antecedent type, which, in the absence of evidence of uplift of the ranges relative to the intervening plains and valleys, is unlikely.

During the 1930 expedition Madigan climbed Mt Sonder and claimed to have been the first European to have done so. It was an interesting facet of the explorer that he insisted on climbing alone although his youthful assistant was anxious to accompany him! His work in the MacDonnell Ranges was a significant contribution to the geology of Australia at a very early stage of the mapping of the continent and a very enterprising project considering the remoteness of the area and the difficulties of travel in those days.

In 1932 Madigan's knowledge of and interest in central Australia led him to being commissioned to assess the prospects at The Granites, where a gold rush had developed. This was during the Depression

and the lure for gold had attracted a large number of people who were ill equipped either mentally or physically to cope with this remote and harsh area. Madigan reported adversely on the gold prospects and a potential human disaster was thus largely averted.

THE SIMPSON DESERT

In addition to introducing Madigan to the folded and faulted uplands of central Australia, the 1929 aerial traverses took him over the most arid areas of the Australian continent, and in particular over extensive fields of longitudinal sand dunes or sand ridges (Fig. 5).

The age and origin of these dune deserts were to become both Madigan's pre-eminent intellectual pursuit and his major claim to enduring and international recognition. Not only were his observations of dunes perceptive but his interpretation of their origin was original and attained considerable notice and acceptance overseas (see e.g. Price 1950). Certain of his observations anticipated some that are now regarded as crucial to the understanding of longitudinal dunes and others broached problems which remain the subject of vigorous debate.

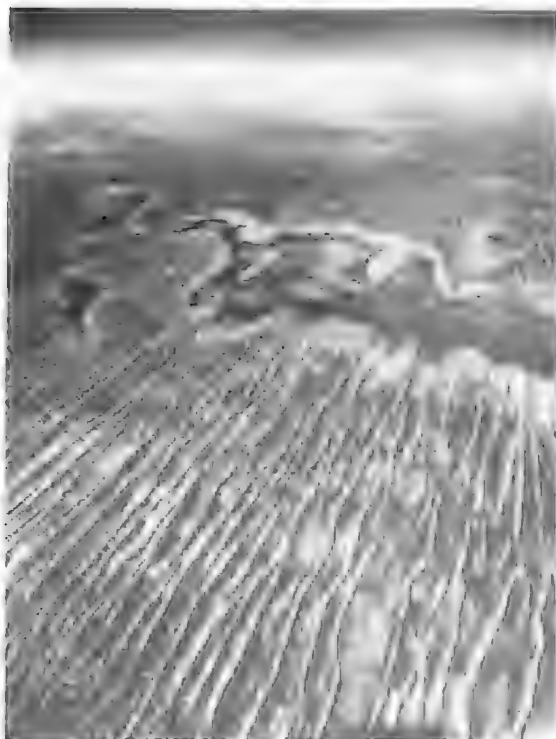


Fig. 5. Oblique air photograph looking north along sand ridges and salinas in the Tirari Desert, just east of Madigan Gulf and south of Cooper Creek. Lake Eyre is in view (top left IRAAF).

Madigan (1936, 1937, 1938, 1946) wrote four papers specifically concerned with the sand ridges of central Australia. Though he had flown over the eastern part of the Great Victoria Desert he was mainly concerned with the Simpson Desert, taken here in its broader connotation and embracing the Tirari and the northern part of the Strzelecki deserts as well as the Simpson proper. In addition, many observations are recorded in "Crossing the Dead Heart" (Madigan 1946b).

Of the papers, the first is perhaps the best known probably because it was the first comprehensive scientific account of an Australian dune desert, but also because it appeared in the prestigious *Geographical Review* published in New York by the American Geographical Society. But it is unquestionably the 1946 paper, published, like all the scientific papers generated by the 1939 expedition, in the *Transactions of the Royal Society of South Australia* which stands as Madigan's sandridge testament. It contains a distillation of the observations, experience and consideration of all of Madigan's desert work. Its publication was delayed six years after the expedition by the intervention of the Second World War; and though there is much to be said for rapid publication, the enforced delay allowed time for reflection, and, more importantly, for the reading and digestion of Bagnold's epochal and still unrivalled "The Physics of Blown Sand" (Bagnold 1941).

Madigan was a brilliant observer both in the air and on the ground. His flights over the deserts convinced him of the essential parallelism and continuity of the sandridges (e.g. Madigan 1937) and he confirmed these findings on the ground. He took bearings on the sandridges in various parts of the desert and found that their trend nowhere varied more than 2° from 332° true (Madigan

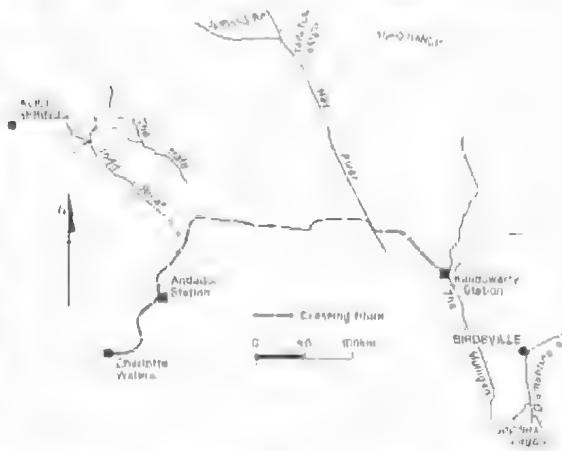


Fig. 6. Route followed by Madigan's party during the crossing of the Simpson Desert, 1939.

1946a, Madigan 1946b). In the course of the 1939 expedition (Fig. 6) he and his party crossed 626 dunes between the Hale and the Mulligan rivers but they saw only one termination of a ridge. Most of the Y- or tuning fork junctions that are typical of the sand ridge desert are open to the south. He noted, as had Gautier (1923, 1935) before him, that the dunefields occupy topographic depressions or "depocentres" (see e.g. Wopfner & Twidale 1967, 1988) and surmised that "The desert is . . . a great alluvial basin, which is still receiving sediment, coarser round the margins, finer toward the lake (Eyre) due to lessening grade. This is surely the origin of the aeolian deposits" (Madigan 1946a, p. 56).

The essential fluvial provenance of the dune sand was confirmed by Carroll's (1944) mineralogical studies; though later work has shown that many of the sand grains have complex histories, having been derived for instance from Permian glacial deposits and Cretaceous marine beds as well as silcrete. But most reach the Lake Eyre Basin and are made available to wind action by way of the many rivers that focus on Lake Eyre (see e.g. Wopfner & Twidale 1967). The red colour of the dunes is due to a ferruginous patina formed on the sand grains. Madigan realised this and pointed out that it forms only in arid conditions, and not, for instance, on beach sands. He remarked (Madigan 1946b, p. 93) that the red patina "takes time to form, so that young dunes are usually white or yellow". Near the Diamantina River he noted that sandy ridges which are built up by sand from the channel are white, but that they gradually become redder toward the interior (i.e. to the north). His practical bent also came to the fore, and enabled him to note that the red veneer was removed when sand grains were boiled in acid! (Madigan 1946b).

Despite the remarkable consistency and repetition of basic dune form, Madigan did not overlook the complexity of the desert, for besides sandridges he encountered salinas and claypans, alluvial flats and gibber plains. He noted the various forms of dune crests and he and his party were forcefully reminded that no desert is rainless when, not for the first time during the 1939 crossing, they experienced rain, and completed the trek into Birdsville along interdune corridors and floodplains heavy with mud.

Madigan observed that the sandridges vary in height between about nine and 30 m above the adjacent interdune corridors. (It is now known that some of the Simpson Desert dunes are 50 m high, but the 1939 expedition did not encounter these higher features). He astutely noticed that there is a relationship between dune height and spacing normal to dune trend (see also Twidale 1981). Thus, he recorded that near Andado, on the western side

of the desert, there are five small ridges which stand on average 123 m apart, in contrast with some large ridges near the eastern margin separated by corridors averaging about 910 m width (Madigan 1946a). The lower slopes or plinths of the dunes are quite well vegetated (mainly spinifex and canegrass), though dunes more than about 15 m high have crests essentially devoid of any plant cover. The ridges are asymmetrical in cross section, with the western slope more gentle than the eastern. And this is generally correct, although later more frequent observations and repeat photography of the same sites have demonstrated that following strong southwesterly blows the asymmetry may be reduced or reversed (see e.g. Wopfner & Twidale 1967, at Pl. XVI).

On the formation of the sandridges, Madigan (1930, 1936, 1946a, 1946b) followed Aufrière (1928) in relating dune trend to dominant wind and, as in the Simpson "the great majority of sand-moving winds are southerly" (Madigan 1946a, p. 59), the NNW trend of the dunes is due to transport and deposition under the influence of these prevalent strong winds. Madigan vehemently reasserted his earlier-stated views that the longitudinal ridges originated as small wavy ridges or strips of sand which coalesced downwind into fewer, larger straight ridges (Madigan 1936, 1946a). After reading and reflecting on Bagnold's observations and experiments, Madigan (1946a) concluded that the initial sand strips had evolved as a result of transverse instability in the airflow. He denied that longitudinal dunes evolve under the influence of cross winds from barchans, as had been suggested by Bagnold, pointing out that there are no barchans in the Simpson, or indeed in any of the Australian dunefields (e.g. Madigan 1937).

In fact, ephemeral barchanoid forms are occasionally developed in the Simpson Desert (e.g. Wopfner & Twidale 1988) and Lancaster (1980) has described from Namibia evidence strongly supportive of Bagnold's mechanism; but, by and large, Madigan was right in respect of the Simpson Desert sandridges and, indeed, of most fields of longitudinal dunes.

Madigan considered that the dunes have extended not only downwind, but also upwind as sand was plastered against the upwind tails of dunes; the former would be widely accepted as demonstrated by repeat observations (see e.g. Wopfner & Twidale 1988), but the latter is dubious. He suggested that lateral winds built up the ridges, which, when they reach a critical height act as obstacles which prevent further sand transport, so that the interdune corridors tend to be swept clean of sand: "All sand becomes trapped on the ridge and travels along it" (Madigan 1946, p. 59).

Most of Madigan's basic observations stand, but, just as the 1939 expedition compelled him to abandon some of his earlier conclusions, so some of his speculations have perforce had to be modified in light of later knowledge. For example, the available data suggest that the wind regime in the Simpson is bidirectional or bimodal, the strong, sand-moving winds blowing from southeast and southwest (Brookfield 1970). This is consistent with the internal structure of the sandridges which was well exposed by seismic tracks cut latitudinally across the Desert during the early nineteen sixties: cross-bedding clearly indicates winds from both southeast and southwest, and this in turn finds support in the temporally varied asymmetry of the ridges (Wopfner & Twidale 1967; see also McKee & Tibbitts 1964).

Again, Madigan asserted that the desert was "in equilibrium" and not extending downwind into the Inko-Turlou-Jervis region. He overlooked the partial "circulation" of sand that returns the wind-blown material to the desert and to the Lake Eyre region by way of such rivers as the Hale, Hay, Todd, Georgina and Diamantina. Also, he was unaware of the importance of source bordering dunes (mounds, lunettes) and other obstacles in the initiation of sand ridges (see e.g. Twidale, 1972, 1981; Dulhunty 1983a).

On the other hand some of Madigan's observations have been overlooked and underrated. For example, that longitudinal dunes develop under the influence of bimodal winds has been suggested by various workers (e.g. Wopfner & Twidale 1967; Twidale 1972, 1981) based on analysis of internal structure and on direct observations of changing asymmetry and sand movement, but it is Tsoar (1978, 1982, 1983) who has, by field experiments, demonstrated that the mechanism involves the "crestal deflection of wind from each of the seasonal modal directions, to flow parallel to the crest line on the lee side of the dune" (Tsoar 1988, p. 597). Although Tsoar's work is properly referred to and praised in Thomas' recent review concerned with linear dune development (Thomas 1988), neither author mentions Madigan's 1939 observation that:

"At Andado, when the wind was about 30 m.p.h. from the southwest and the crests were 'smoking', it was noted that on the side of the crest, the wind at the surface was blowing along the ridge and even upward toward the summit and carrying sand northwards and upwards along the steep slip-slope". (Madigan 1946a, p. 61)

Nevertheless Madigan's work on sandridge development was well received by the international scientific community.

Madigan's views on the age of the dunefields stand in marked contrast with his emphatic certainty regarding the evolution of dunes. His

statements on the subject are equivocal and in places contradictory, though on balance, and taking his indirect as well as his explicit statements into account, he seems to have favoured a recent and continuing age for the forms. On the other hand such ambivalence is probably justified, for, as will be recounted, the evidence concerning the age of the dunes is seemingly contradictory and the question is still being argued.

Madigan considered the silcrete which still occupies large areas of central Australia to have been of late Cainozoic age, having been formed as the B-horizon of a soil during what he called "genial" periods of the Pleistocene (Madigan 1938, p. 27, p. 56). He then suggested that the dunes are self, stating that they formed during a changeover from pluvial Pleistocene vegetation to the present desertic cover of spinifex and kangaroo (Madigan 1946a). He attributed the "live" sand of the Cooper and Diamantina to the depredation of the rabbit, and to (over) stocking (Madigan 1938, p. 27). Yet he stated (Madigan 1946a) that the smaller dunes and the flanks of the larger ones are fixed but that the crests of the latter are active, and that sandridge building has been greatly slowed down though it is still not quite dead. He speculated (Madigan 1938) that the desert must surely have been more arid when the sandridges formed. Yet "No valid reason presents itself to justify the widely held view that aridity was greater in the past when the sandridges had their birth", pointing to the lack of evidence for water table lowering or retreat of vegetation (e.g. Madigan 1938, p. 26). Some of these and other statements can be, and have been, taken to suggest that Madigan considered the dunefield to be stable and a relic of the recent past (e.g. Sprigg 1979, 1980). Some, however, can be construed as indicating a belief in the essentially modern age and activity of the dunes.

If aridity is taken to favour dune activity, then, according to Madigan (1946a, p. 62) "aridity may have reached its maximum", and elsewhere he dismissed the possibility of pluvial/arid alternations during the Pleistocene, and considered that there had been a swing to aridity beginning at the close of the Pleistocene glaciation (Madigan, 1946a). Again: "The origin and history of the Simpson Desert sandridge . . . originating when aridity set in during the late Pleistocene by wind action on the alluvial deposits, mainly unconsolidated, on the great plains of the Lake Eyre Basin" (Madigan 1946a, p. 59).

Madigan was evidently unaware of Ratcliffe's (1936, 1937) studies of the southern and eastern parts of the desert which clearly demonstrate the contemporary movement of dunes. Modern, though probably spasmodic, movement of dune ridges has

been measured (Wopfner & Twidale, 1988) and is supported by many types of indirect evidence. Over wide areas the sandridges overlie fossiliferous alluvial or lacustrine sediments of late Pleistocene or even early Holocene age (Wopfner & Twidale 1967, 1988; Mabbitt & Sullivan 1968; Twidale 1972, 1981). Elements of an older dunefield have been noted (Wopfner & Twidale 1967, 1988), and the possibility of pluvial and arid alternations during the Pleistocene cannot readily be ruled out. For instance, the ancestor of Lake Eyre, Lake Dieri, was an immense body of water during the late Pleistocene (e.g. King 1956; Löffler & Sullivan, 1976; Dulhunty 1983b), so, if the climate has changed during the Holocene or Late Holocene it is surely strange that dune trend is not in process of adjustment?

It is clear from Madigan's comments and conclusions that he did – at times perhaps? – believe that the dunes are still active. Implicit in his observation that the dunes bordering the Diamantina near Birdsville are white and therefore young is the conclusion that they are intrinsically contemporary. Similarly the deflection of sand over the smoking dunes at Andado, and the occurrence of small wavy strips or ridges, surely also imply essential contemporaneity?

The reason for Madigan's confused and confusing statements about the age of the dunes is that the problem is itself confused and confusing. By and large, however, he added immensely to our knowledge of sand ridges both in the Simpson and in other parts of the world. In 1950 the late Armstrong Price published a lengthy review of then recent work on dunes in the Sahara and in central Australia. He concluded that "The chief contribution of Madigan's study of sand dunes is its seemingly satisfactory explanation of the origin and development of longitudinal dunes, based on Bagnold's wind-tunnel experiments and on his own field work and study of the literature" (Price 1950, p. 465).

LAKE EYRE

Madigan's interest in and exploration of Lake Eyre began with his flight across the salina in 1929 as part of his aerial reconnaissance of central Australia. The plane flew low over the salt crust, touching down to leave wheel tracks, though not landing on the soft surface. Mound springs were noted and photographed on the western side of the lake but no other water was sighted (Madigan 1930). After the 1939 crossing of the sand ridge desert, Madigan and his party returned to Marree from Birdsville along the eastern shore of Lake Eyre.

During these land traverses Madigan was his usual busy self. Little escaped his notice. The

thickness of the salt crust and the slight but definite slope of the lake bed (see e.g. Dulhunty 1987) were determined at several places. It was observed that where the shore trended latitudinally the sand ridges approaching from the south terminated "abruptly and steeply" on the shore, whereas those to the north of the lake bed rose gently over gypseous slopes to merge with the dunes beyond (Madigan 1946a, p. 139).

Shallow, but quite extensive, bodies of water were seen on the lake bed in 1939, but Madigan formed the opinion that the "lake is never covered all over with water at any time" (Madigan 1946a, p. 134). This conclusion has been shown to be incorrect several times over the past 40 years (see e.g. Bonython & Mason 1953; Kotwicki 1986) and is likely to be repudiated again this year (1990). Nevertheless Madigan contributed to the ongoing investigation of Lake Eyre, and Madigan Gulf, a major embayment forming the southeastern part of Lake Eyre North, is named after him.

Conclusion

In physique, character and personality, C. T. Madigan was a man of great stature. His was a questing mind, wide-ranging yet tenacious, imaginative yet rigorous.

His winter sledge journey on the ice plateau of Adelie Land was an extraordinary test of strength, stamina and character, and his travels in central Australia, whether by air or on the ground, and undertaken under conditions that would today be considered arduous, still stand as truly remarkable feats.

Even in Australia, Madigan's field work was constrained both by the absence of base maps other than pastoral maps, by the absence of good roads and by the travel limitations of horse, camel or foot. Eventually he pioneered aerial reconnaissance and aerial photography; and he lived to see the almost universal availability of four-wheel-drive vehicles for outback work, but most of his field work was of the heroic type, and he became a considerable bushman, utterly at ease in the field situation (Fig. 7).

Madigan's values and standards were those of a bygone age but are none the worse for that. He was strongly and actively patriotic. He believed in physical fitness. He lived by the ideal of service. He possessed a great sense of humour. As a teacher he was stimulating, as well as innovative, and always considerate of his students. He was of a practical bent, and he made sure that his students became aware of the mining, engineering and economic aspects of their discipline. Madigan was a natural leader, and as the years passed he found irksome his position as second in command to Mawson,



Fig. 7. Madigan in camp, MacDonnell Ranges, 1930 (E. A. Rudd).

himself also a striking personality. Perhaps inevitably, an element of tension developed between them. As a departmental staff of only two for much of their joint careers, their respective roles were in some measure resolved, particularly in respect of their research areas, when Madigan elected to concentrate his energies on central Australia and on the problems posed by sand ridges.

It has been said that the geomorphological study of deserts has been bedevilled by the enthusiastic amateur responsible for an "unpalatable farrago of descriptive data" derived from rapid reconnaissance surveys (Cooke & Warren 1973, p. 5). Desert landforms and particularly mobile sand dunes are attractive, even spectacular, features. Their nature and origin inevitably raise questions in the questing mind and it is not surprising therefore that "enthusiastic amateurs" or laymen have been drawn into over-imaginative and even imprudent speculations. Charles Sturt, for instance, was puzzled by both the stony desert and the sand dunes he encountered during his journeys in the interior of Australia in 1845. He suggested that the dunes were gigantic ripples formed on an ancient sea floor and later exposed (Sturt 1849); an interpretation that is untenable but at least based in natural

processes rather than divine intervention. But scientists like Madigan, though not trained geomorphologists were nevertheless well equipped to make perceptive observations and draw astute inferences from them.

In this regard it is interesting to note that Madigan, like Bagnold, was trained in engineering, a discipline not inimical to close observation and the linking of natural processes and their results. Furthermore it can be argued that lacking the prejudices and constraints that inevitably result from any formal training in a discipline, such "outsiders" have some advantages in that they are more likely to develop unorthodox explanations (see e.g. Carey 1976).

Madigan was a man of eclectic interests. Possessed of a keen eye and abiding curiosity, he had the ability to get to and work in uncomfortable places. He was one of the last of the great scientific travellers. He notably advanced our knowledge of central Australia, so much so that his name will be forever linked with the sand ridges of the Simpson Desert to which he directed so much time and energy and to the nature of which he brought illumination and understanding.

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TRANSACTIONS OF THE

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VOL. 114, PART 4

NEW SPECIES OF *CASTIARINA* (COLEOPTERA: BUPRESTIDAE) AND REDESCRIPTIONS OF *C DIVERSA* (KERREMANS) AND *C ELDERI* (BLACKBURN)

BY *S. BARKER**

Summary

Castiarina diversa (Kerremans) 1900 is resurrected from synonymy and together with *C. elderi* (Blackburn) 1892 is redescribed and illustrated. The following ten new species of *Castiarina* (*abdit*a sp.nov., *aurantia* sp.nov., *creta* sp.nov., *daedalea* sp.nov., *galactica* sp.nov., *indigohumerosa* sp.nov., *indigoventricosa* sp.nov.; *nota* sp.nov., *palliata* sp.nov., *rediviva* sp.nov.) are described and illustrated.

KEY WORDS: New species, *Castiarina*, Coleoptera, Buprestidae.

NEW SPECIES OF *CASTIARINA* (COLEOPTERA: BUPRESTIDAE) AND REDESCRIPTIONS OF *C. DIVERSA* (KERREMANS) AND *C. ELDERI* (BLACKBURN)

by S. BARKER*

Summary

BARKER, S. (1990) New species of *Castiarina* (Coleoptera: Buprestidae) and redescrptions of *C. diversa* (Kerremans) and *C. elderi* (Blackburn). *Trans. R. Soc. S. Aust.* 114(4) 169-178, 30 November, 1990.

Castiarina diversa (Kerremans) 1900 is resurrected from synonymy and together with *C. elderi* (Blackburn) 1892 is redescribed and illustrated. The following ten new species of *Castiarina* (*abditu* sp.nov., *aurantia* sp.nov., *creta* sp.nov., *daedalea* sp.nov., *galactica* sp.nov., *indigohumerosa* sp.nov., *indigoventricosa* sp.nov., *nota* sp.nov., *palliatu* sp.nov., *rediviva* sp.nov.) are described and illustrated.

KEY WORDS: New species, *Castiarina*, Coleoptera, Buprestidae.

Introduction

In her revision of the tribe Stigmoderini (Buprestidae), Gardner (1990) elevated the three major sub-divisions of *Stigmodera* to separate genera. Of the Australian genera, *Stigmodera* is closely allied to *Themognatha*, *Calodema* and *Metaxymorpha* while *Castiarina* stands alone. A series of *Castiarina* specimens collected in W.A. by Mr M. Powell, were compared with the male holotype of *C. elderi* (Blackburn). Although some specimens belonged in that species, the rest represented three separate taxa, one of which was *C. diversa* (Kerremans) clearly not a synonym of *C. elderi*. The other two are described and illustrated, together with another species in the *C. elderi* complex found in South Australia, and seven other species. *C. elderi* and *C. diversa* are redescribed and illustrated.

Materials and Methods

Male genitalia were prepared and displayed by the method described by Barker (1987). All specimens were measured using a dissecting microscope with a 'bombsight' crosshair in the eyepiece and a circular micrometer attached to the stage for maximum accuracy. The measurements are presented as a mean and standard error. Abbreviations used in the text for museum and private collections following Watt (1979) are: BMNH British Museum (Natural History), London; RMBB Royal Museum Belgium, Brussels; SAMA South Australian Museum, Adelaide; NMVA National Museum of Victoria, Melbourne;

WAMA Western Australian Museum, Perth; WADA Department of Agriculture, South Perth; GBYA Mr G. G. Burns, Mornington; HDWA Mr H. Demarz, Wanneroo; MPWA Mr M. Powell, Melville; MHSA Mr T. M. S. Hanlon, Sydney; RMNA Mr. R. Mayo, Narara; ASSA Mr A. Sundholm, Sydney.

Castiarina elderi (Blackburn), 1892

FIGS 1F, 2A

Stigmodera elderi Blackburn, 1892: 36. Kerremans, 1903: 212 (*ederi* lapsus). Carter, 1916: 87, 90, 101; 1929: 244; 1931: 356. Obenberger, 1934: 701. Barker, 1979: 17; 1983: 154; 1986: 30.

Stigmodera diversa Kerremans, 1900: Carter, 1916: 87, 101 (new syn.); 1929: 294; 1931: 356. Obenberger, 1934: 702. Barker, 1979: 17; 1986: 30.

Holotype. ♂, Victoria Desert, Sept., Mr Helms, SAMA.

Colour. Head blue, basally dark blue with large yellow frontal spot. Antennae blue. Pronotum medially dark blue, laterally yellow. The shape of the central blue mark was described by Blackburn (1892 p.37) 'as resembling that of a bust of a human figure with the head and the arms truncated, the neck reaching to the front margin of the segment.' Scutellum blue. Elytra yellow with the following dark blue markings: narrow basal margin; pre-medial fascia not reaching margin, ends angled anteriorly 'resembling the shape of a boot on each side' (Blackburn 1892 p.37); broad post-medial fascia; apical mark. Fascia and apical mark connected along suture. Ventral surface yellow with dark blue sutures and edges of abdominal segments, S_4 , S_5 , S_6 with lateral dark blue spots on each side. Legs blue. Hairs silver.

Shape and sculpture. Head closely punctured, no median sulcus, very short muzzle. Antennae compressed, antennomeres: 1-4 obconic; 5-11 toothed. Pronotum closely punctured, narrow basal

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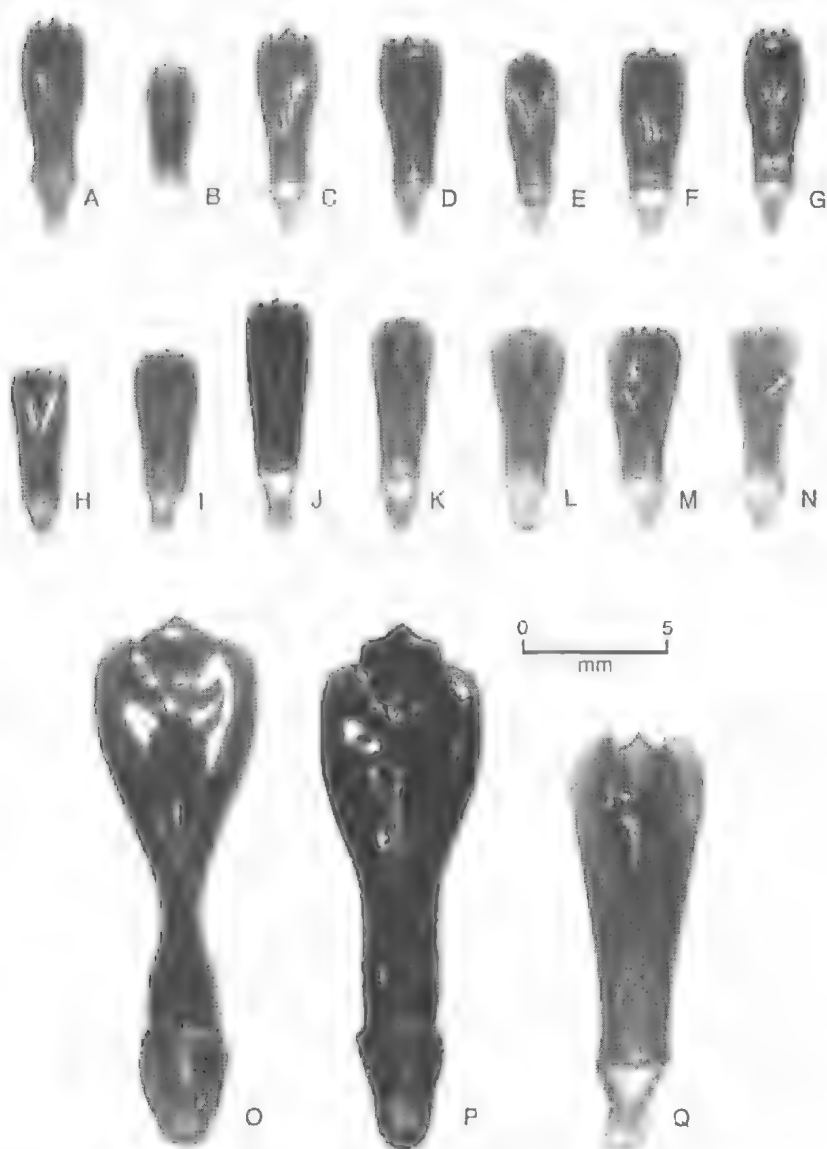


Fig. 1. Photomicrographs of male genitalia of *Castiarina* spp. A, *Castiarina galactica* sp.nov., B, *C. pallidiventris* (C & G), C, *C. creta* sp.nov., D, *C. aurantia* sp.nov., E, *C. diversa*, (Kerremans), F, *C. elderi* (Blackburn), G, *C. rediviva* sp.nov., H, *C. indigohumerosa* sp.nov., I, *C. atricollis* (Saunders), J, *C. palliata* sp.nov., K, *C. nota* sp.nov., L, *C. crux* (Saunders), M, *C. abdita* sp.nov., N, *C. distinguenda* (Saunders), O, *C. indigoventricosa* sp.nov., P, *C. jeanae* (Barker), Q, *C. daedalea* sp.nov.

fovea; apical margin projecting medially, basal margin almost straight; laterally angled inwards from base, then rounded from base to apex (widest medially) rounded to apex. Scutellum scutiform, without punctures, glabrous, flat. Elytra punctate-striate, intervals convex, punctured; laterally angled out from base, rounded at humeral callus, concave,

rounded posteromedially and narrowed to trispinose apex; small marginal spine, larger medial spine, small sutural spine, margin rounded between spines, apices hardly diverging. Ventral surface with shallow punctures, edges of abdominal segments glabrous, few short hairs. S₇: truncate both sexes, medially indented.

Size. Males, $11.0 \pm 0.10 \times 3.9 \pm 0.05$ mm (8). Females, $12.0 \pm 0.21 \times 4.3 \pm 0.09$ mm (5).

Male genitalia. (Fig. 1F). Parameres diverging from basal piece, rounded posteromedially, parallel-sided, rounded to apex. Median lobe pointed, sides acutely angled away. Apophysis of basal piece medium width, flattened at apex.

Distribution: W.A.: Great Victoria Desert.

examined a series collected by Mr M. Powell on the flowers of *Wettlia* sp. from the southwestern edge of the Great Victoria Desert.

Castiarina diversa (Kerremans) 1900

FIGS 1E, 2B

Stigmodera diversa Kerremans, 1900: 317; 1903: 207. **Holotype.** ♀, Australia, French, BMNH.

Colour. Head; blue, basally dark blue or bronze-green, yellow frontal spot. Antennae blue. Pronotum dark blue or bronze, laterally yellow. Scutellum dark blue. Elytra yellow with orange margin and following dark blue markings: narrow basal margin; pre-medial fascia not reaching margin, ends projecting and angled over humeral callus; post-medial fascia reaching margin; apical mark. Ventral surface yellow, sutures and edges of abdominal segments blue or green, S_1 , S_2 , S_3 with lateral blue spots on each side. Legs blue or green. Hairs silver.

Shape and sculpture. Head closely punctured, no median sulcus, very short muzzle. Antennae compressed, antennomeres: 1-3 obconic; 4 $\frac{1}{2}$ -toothed; 5-11 toothed. Pronotum closely punctured, small basal fovea; apical margin broadly projecting medially, basal margin bisinuate; laterally parallel-sided, then rounded to apex (widest medially). Scutellum scutiform, without punctures, glabrous, flat. Elytra punctate-striate, intervals convex, punctured; laterally angled out from base, rounded at humeral callus, concave, rounded posteromedially and narrowed to trispinose apex; sharp marginal spine, larger medial spine, smaller sutural spine, margin rounded between spines, apices hardly diverging. Ventral surface with shallow punctures, edges of abdominal segments glabrous, few short hairs. S_1 : male truncate; female, truncate, slightly indented medially.

Size. Males, 8.5 ± 0.19 mm \times 3.0 ± 0.07 mm (10). Females, $8.8 \pm 0.24 \times 3.2 \pm 0.08$ mm (5).

Male genitalia. (Fig. 1E). Parameres slightly diverging from basal piece, rounded posteromedially, then more or less parallel-sided, rounded to apex. Median lobe blunt, sides angled away. Apophysis of basal piece medium width, narrowed, rounded at apex.

Distribution: W.A.: Wubin, Morowa, Yalgon, Kalgoorlie, Mt Magnet, Norseman, Zanthus.

Remarks. Barker (1979, 1986) followed Carter (1916, 1929, 1931) and Obenberger (1934) in listing *C. diversa* (Kerremans) 1900 as a synonym of *C. elderi* (Blackburn) 1892. Comparison of the holotypes of *C. elderi* and *C. diversa* indicates that the two taxa are not conspecific. *C. diversa* (Fig. 2B) is smaller than *C. elderi* (Fig. 2A) and does not have the same

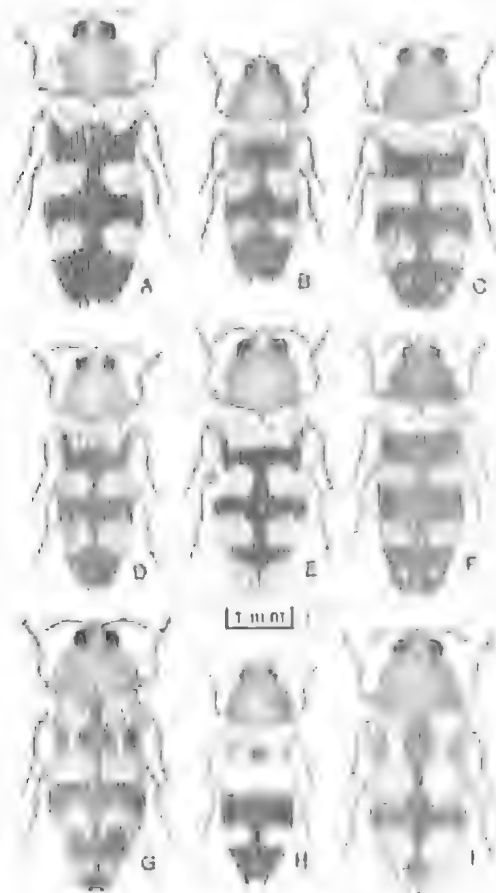


Fig. 2. Habitus illustrations of the following *Castiarina* species: A, *Castiarina elderi* (Blackburn), B, *C. diversa* (Kerremans), C, *C. crediviva* sp. nov., D, *C. (relu)* sp. nov., E, *C. galactica* sp. nov., F, *C. aurantia* sp. nov., G, *C. abdita* sp. nov., H, *C. indigohumerosa* sp. nov., I, *C. nota* sp. nov.

Remarks. The type series in SAMA consists of: male holotype labelled Victoria Desert, Sept., Mr Helms, Type and is clearly the specimen described by Blackburn; 1 ♂ and 2 ♀♀ specimens labelled 'Kalgoorlie, Type,' which belong to another species described herein. The holotype was until recently the only specimen known of this species. I have

pattern on the pronotum. The elytra have a dark yellow margin, whereas *C. elderi* has pale yellow elytra. The male genitalia of *C. elderi* are broader than those of *C. diversu* (Figs 1E, 1F) and distributions of the two taxa differ. Thus I consider each a valid species. Adults have been collected on the flowers of *Leptospermum* sp. and *Eremophila* sp.

Castlarina creta sp. nov.

FIGS 1C, 2D

Holotype, ♂, 48 km NE Cowell, S.Aust., 14.x.1989, S. Barker, SAMA J 21231.

Allotype, ♀, 10 km E 35 km post N Cowell, Whyalla Hwy, 1.x.1982, S. Barker, J. Gardner, H. Vanderwoude, SAMA J 21232.

Paratypes, S.Aust.: 2 ♂♂, same data as allotype, SAMA; 1 ♂, 1 ♀, 53 km NE Cowell, 13.xi. 1974, S. Barker, SAMA.

Colour, Head bronze, pale yellow frontal spot. Antennae blue. Pronotum: medially bronze with yellow reflections; laterally pale yellow. Scutellum dark blue. Elytra pale yellow, lateral margin brown-orange with following dark blue markings: narrow basal margin; pre-medial fascia not reaching margin, ends angled anteriorly; broad post-medial fascia; apical spade-shaped mark reduced in some specimens to short pre-apical fascia not reaching margin and mark around spines or expanded in some specimens to mark covering whole apex. Fascia and apical mark connected along suture. Ventral surface pale yellow, sutures and edges of abdominal segments testaceous or blue. Legs blue. Hairs silver.

Shape and sculpture. Head closely punctured, small median sulcus, very short muzzle. Antennae compressed, antennomeres: 1-4 obconic; 5-11 toothed. Pronotum closely punctured, small basal fovea; apical margin projecting medially, basal margin barely bisinuate; laterally angled inwards from base, rounded to apex (widest medially). Scutellum scutiform, without punctures, glabrous, medially excavate. Elytra punctate-striate, intervals convex, punctured; laterally angled out from base, rounded at humeral callus, concave, rounded posteromedially and narrowed to trispinose apex; small marginal spine, larger median spine, small sutural spine, margin rounded between spines, apices hardly diverging. Ventral surface with shallow punctures, edges of abdominal segments glabrous, sparse short hair. *S*₁: male truncate; female truncate, slightly indented medially.

Size. Males, $9.8 \pm 0.43 \times 3.4 \pm 0.20$ mm (4). Females, $10.0 \pm 0.62 \times 3.6 \pm 0.22$ mm (2).

Male genitalia, (Fig. 1C). Parameres parallel-sided from basal piece, rounded outwards medially, rounded to apex. Median lobe pointed, sides angled away. Apophysis of basal piece narrowed, rounded to apex.

Remarks. *C. creta* sp. nov. is closest to *C. elderi*, but differs in colour, distribution and structure of the male genitalia. All specimens have been collected on *Leptospermum coriaceum* (F. Muell.) Cheel. Name derived from *creta* L. 'chalk'.

Castlarina aurantia sp. nov.

FIGS 1D, 2F

Holotype, ♂, Pindar Paddock, Tallering Stn, W.A., 21.ix.1989, S. Barker, WAMA.

Allotype, ♀, 10 km NE Mt Magnet, W.A., 20.ix.1980, S. Barker, D. J. Williams, WAMA.

Paratypes, W.A.: 5 ♂♂, 4 ♀♀, same data as allotype, SAMA, WAMA; 2 ♂♂, same data as holotype, SAMA; 1 ♂, 1 ♀, 36 km W Sandstone, 20.ix.1985, M. Powell, MPWA; 2 ♂♂, Tallering Stn, 22/23.ix.1989, S. Barker, SAMA, 1 ♀, 77 km W Yalgoo, 22.ix.1980, G. G. Burns, GBVA; 1 ♂, 62 km NE Wubin, 7.x.1980, G. G. Burns, GBVA; 1 ♂, 42 km N Wubin, 11.x.1980, G. G. Burns, GBVA; 2 ♀♀, 46 km N Wubin, 11.x.1980, G. G. Burns, GBVA; 2 ♂♂, 48 km N Wubin, 11.x.1980, G. G. Burns, GBVA; 2 ♂♂, 2 ♀♀, 38.7 km N Wubin, 17.ix.1987, G. G. Burns, GBVA.

Colour. Head: apically blue; basally dark blue with elongate yellow frontal spot. Antennae blue. Pronotum: medially dark blue; laterally orange. Scutellum blue. Elytra orange with the following dark blue markings: narrow basal margin; pre-medial fascia not reaching margin, ends projecting anteriorly to humeral callus; post-medial fascia reaching margin; apical mark with two yellow spots in some specimens, reduced to short pre-apical fascia in one specimen. Fascia and apical mark connected along suture. Ventral surface deep orange, sutures testaceous or heavily marked dark blue. *S*₁, *S*₂, *S*₃, with lateral dark blue marks on each side. Legs blue. Hairs silver.

Shape and sculpture. Head closely punctured, very small median sulcus, very short muzzle. Antennae compressed, antennomeres: 1-3 obconic, 4 bis toothed; 5-11 toothed. Pronotum closely punctured, small basal fovea; apical margin projecting medially, basal margin barely bisinuate; laterally parallel-sided at base, rounded to widest posteromedially, narrowed to apex. Scutellum scutiform, without punctures, glabrous, flat. Elytra punctate-striate, intervals convex, punctured; laterally angled out from base, rounded at humeral callus, concave, rounded posteromedially, tapered then rounded to

trispinose apex; small marginal spine, larger medial spine, small sutural spine, margin rounded between spines, apices diverging. Ventral surface with shallow punctures, edges of abdominal segments glabrous, moderately hairy, hairs medium length. S_7 : male truncate; female truncate, slightly indented medially.

Size. Males, 10.4 ± 0.14 mm \times 3.7 ± 0.08 mm (18). Females, 10.6 ± 0.21 mm \times 3.7 ± 0.07 mm (10).

Male genitalia. (Fig. 1D). Parameres diverging from basal piece, rounded anteromedially, parallel-sided then rounded to apex. Median lobe pointed, sides acutely angled away. Apophysis of basal piece medium width, narrowed, rounded to apex.

Remarks. *C. aurantia* sp. nov. is closest to *C. elderi*. The adults of this species have been found associated with *Eremophila*, *Thryptomene* and *Scholtzia* species. Their colour in life separates them from *C. elderi*, but after death it fades rapidly to pale yellow. The name is derived from *aurantium* L. 'orange'.

Castiarina rediviva sp. nov.

FIGS 1G, 2C

Holotype. ♂, 4 km W Zanthus, W.A., 21.x.1989, M. Powell, WAMA.

Allotype. ♀; same data as holotype WAMA.

Paratypes. W.A.: 1 ♂, 3 ♀♀, same data as holotype, MPWA & SAMA; 1 ♂, 2 ♀♀, Kalgoorlie from type series of *C. elderi* Blackburn, SAMA, S.Aust.: 4 ♂♂, 4 ♀♀, 45 km E S.Aust./W.A. border, Eyre Hwy, 22.1.1987, A. Sundholm & J. Bugeja, ASSA & SAMA.

Colour. Head dark blue with purple reflections. Antennae blue. Pronotum dark blue with purple reflections. Scutellum blue. Elytra yellow with orange margin and following dark blue markings: narrow basal margin; pre-medial fascia not reaching margin, ends projecting over humeral callus; post-medial fascia reaching margin; apical mark (in six out of nine specimens enclosing a yellow spot on each side, in two solid, in one reduced to short fascia). Fascia and apical mark connected along suture. Ventral surface yellow with blue sutures and edges of abdominal segments S_1 , S_2 , S_3 with lateral blue spots on each side. Legs blue. Hairs silver.

Shape and sculpture. Head closely punctured, no median sulcus, very short muzzle. Antennae compressed, antennomeres: 1-4 obconic; 5-11 toothed. Pronotum closely punctured, small basal fovea extending forwards to middle as impressed line; apical margin projecting medially; basal margin barely bisinuate; laterally parallel-sided at base, rounded to apex. Scutellum scutiform, without punctures, glabrous, flat. Elytra punctate-striate,

intervals convex, punctured; laterally angled out from base, rounded at humeral callus, concave, rounded posteromedially and narrowed to trispinose apex; small marginal spine, larger medial spine, smaller sutural spine, margin rounded between spines, apices hardly diverging. Ventral surface with shallow punctures, edges of abdominal segments glabrous, hairs short. S_7 : male truncate; female truncate, slightly indented medially.

Size. Males, 10.7 ± 0.24 mm \times 3.9 ± 0.10 mm (7). Females, 11.5 ± 0.36 mm \times 4.1 ± 0.10 mm (10).

Male genitalia. (Fig. 1G). Parameres slightly diverging from basal piece, rounded posteromedially, parallel-sided, rounded to apex. Median lobe pointed, sides acutely angled away. Apophysis of basal piece medium width, narrowed, rounded to apex.

Remarks. *C. rediviva* sp. nov. is closest to *C. elderi*. It is a darker colour than *C. elderi*, but lacks the distinctive dark mark on the pronotum. Male genitalia are distinct, those of *C. rediviva* are narrower than those of *C. elderi* (Fig. 1F) and a different shape. Recently collected specimens were taken on *Eremophila* species. Name derived from *redivivum* L. 'renewed'.

Castiarina galactica sp. nov.

FIGS 1A, 2E

Holotype. ♂, Mon Repos, Mosman Park, W.A., 27.xi.1954, S. Barker, SAMA 1 21233.

Allotype. ♀, Mon Repos, Mosman Park, W.A., 12.xi.1957, S. Barker, SAMA 1 21234.

Paratypes. W.A.: 1 ♂, 2 ♀♀, Wannaru (sic), H. W. Brown, RMBB; 1 ♀, Swan River, Lea, SAMA, 1 ♂, Calaby, 27.xi.1977, M. Powell, MPWA.

Colour. Head bronze with green and purple reflections, large milky yellow frontal spot. Antennae green. Pronotum medially bronze with green and purple reflections, laterally milky yellow. Scutellum blue. Elytra milky yellow with following dark blue markings: narrow basal margin; pre-medial fascia not reaching margin, extending anteriorly at ends to humeral callus, extending anteriorly on suture; post-medial fascia reaching margin; pre-apical mark. Fascia and apical mark connected along suture. Ventral surface milky yellow with green-blue markings on sutures and edges of abdominal segments and green-blue lateral spot on each side of abdominal segments, S_1 , S_2 , S_3 . Legs green. Hairs silver.

Shape and sculpture. Head closely punctured, no median sulcus, short muzzle. Antennae, antennomeres: 1-3 obconic; 4 1/2-toothed; 5-11 toothed. Pronotum closely punctured, basal fovea extending to apical margin as impressed line, basal

notches on each side more marginal than medial; apical margin projecting medially; basal margin bisinuate; laterally parallel-sided at base, rounded to widest part posteromedially, rounded and narrowed to apex. Scutellum scutiform, few punctures, glabrous, excavate. Elytra punctate-striate, intervals convex and punctured; laterally angled out from base, rounded at humeral callus, concave, rounded posteromedially and narrowed to trispinose apex; small marginal spine, wide blunt medial spine, very small sutural spine, margin rounded between spines, apices diverging. Ventral surface with shallow punctures, edges of abdominal segments glabrous, few short hairs. *S.*: males truncate; females truncate and indented medially. Size. Males, $9.7 \pm 0.48 \times 3.5 \pm 0.23$ mm (4). Females, $11.0 \pm 0.20 \times 3.9 \pm 0.06$ mm (3).

Male genitalia. (Fig. 1A). Parameres parallel-sided basally, rounded posteromedially, parallel-sided, rounded apically. Median lobe sharp, sides acutely angled away. Apophysis of basal piece medium width, rounded apically.

Remarks. *C. galactica* sp. nov. is closest to *C. pallidiventris* (C & G) but differs in the structure of the male genitalia (Figs 1A, 1B) and in not having a red elytral margin. Adults are found on the flowers of *Melaleuca huegelli* R.Br. Name derived from *gala* Gr. 'milk'.

***Castiarina abdita* sp. nov.**
FIGS 1M, 2G

Holotype. ♂, 30 km W Mullewa, W.A., 12.ix.1987; M. Powell & Jones, WAMA.

Allotype. ♀, 114 km S Billabong Roadhouse, Great Northern Hwy, 20.ix.1989, S. Barker, WAMA.

Paratypes. W.A.: 1 ♀, same data as holotype, MPWA; 1 ♀, 34 km S Billabong Roadhouse, 15.ix.1985, M. Powell, MPWA; 1 ♂, 2 ♀♀, Teninewa, H. W. Brown, NMVA; 1 ♂, Carnarvon, H. W. Brown, NMVA.

Colour. Head grey-blue, muzzle blue. Antennae, antennomeres: 1-2 grey-blue; 3-11 bronze. Pronotum grey-blue medially; red laterally. Scutellum blue. Elytra red with the following blue markings: narrow basal margin; pre-medial fascia not reaching margin, ends expanded anteriorly over humeral callus on each side or represented by an elongate mark over each humeral callus and one on suture; post-medial fascia reaching margin, convex anteriorly; pre-apical mark; mark covering apex, all marks connected along suture. Ventral surface: prosternum mainly red, some sutures blue; meso and metasterna predominantly blue; abdominal segments red. Legs blue. Hairs silver. **Shape and sculpture.** Head closely punctured, broad

median sulcus, short muzzle. Antennae, antennomeres: 1-3 obconic; 4-11 toothed. Pronotum closely punctured, basal fovea extending anteriorly to middle as glabrous line; apical margin projecting medially, basal margin barely bisinuate; laterally angled inwards from base, rounded to widest part posteromedially, rounded and narrowed to apex. Scutellum scutiform, punctured, excavate. Elytra punctate-striate, intervals convex, punctured; laterally angled outwards from base, rounded at humeral callus, concave, rounded posteromedially and tapered, rounded to trispinose apex; blunt marginal spine, small blunt sutural spine, margin rounded and indented between spines, apices diverging, apical margin subserrate. Ventral surface with shallow punctures, edges of abdominal segments glabrous, moderately hairy, hairs short. *S.*: males truncate; females rounded.

Male genitalia. (Fig. 1M). Parameres parallel-sided at base, diverging posteromedially, rounded to apex. Median lobe pointed, sides acutely angled away. Apophysis of basal piece narrow, rounded apically. Size. Males, $11.2 \pm 0.32 \times 4.2 \pm 0.11$ mm (4). Females, $12.8 \pm 0.22 \times 5.1 \pm 0.12$ mm (5).

Remarks. *C. abdita* sp. nov. has been confused with *C. distinguenda differens* (Carter). It is a larger species than *C. distinguenda*; male genitalia are broader apically (Fig. 1N), the dorsal surface is convex (flat in *C. distinguenda*) and the elytral markings are blue (black in *C. distinguenda*). Red coloration in *C. distinguenda* fades to yellow soon after death whereas it does not in *C. abdita*. Name derived from *abditus* L. 'hidden'.

***Castiarina indigohumerosa* sp. nov.**
FIGS 1H, 2H

Holotype. ♂, Willaré, W.A., 24.v.1989, H. Demaree, WAMA.

Allotype. ♀, same data as holotype WAMA.

Paratypes. W.A.: 3 ♂♂, 8 ♀♀, same data as holotype HDWA, SAMA; 4 ♂♂, Willaré, 21.v.1989, H. Demaree, HDWA; 1 ♂, 9 ♀♀, 10 km N Willaré, H. Demaree, 22.v.1989 HDWA; 1 ♀, Great Sandy Desert, 5.vi.1978, P. M. Thomas, SAMA; 1 ♂, Great Sandy Desert, Ridge Rd, Anketell, 11.v.1977, A. S. George, WADA.

Colour. Head blue, Antennae, antennomeres: 1-2 blue; 3-11 bronze. Pronotum and scutellum bright blue. Elytra yellow with the following dark blue markings: narrow basal margin; remnant pre-medial fascia represented by spot near each margin and larger spot on suture; broad post-medial fascia reaching margin; apical mark, the last two marks connected along suture. Ventral surface and legs blue. Hairs silver.

Shape and sculpture. Head closely punctured, median sulcus, very short muzzle, eyes bulbous. Antennae compressed, antennomeres: 1-3 obconic; 4-11 toothed. Pronotum closely punctured, small basal fovea extending to middle as impressed line; apical margin projecting medially, basal margin barely bisinuate; laterally parallel-sided at base, angled outwards, rounded to widest part anteromedially, rounded to apex. Scutellum scutiform, glabrous, flat. Elytra punctate-striate, intervals convex, punctured; laterally angled out from base, rounded at humeral callus, concave, rounded posteromedially and narrowed to bispinose apex; sharp marginal spine, small sharp sutural spine, margin rounded and indented between spines, apices diverging. Ventral surface with shallow punctures, edges of abdominal segments glabrous, sparse short hair. *S.*: males truncate and slightly indented medially; females truncate and indented medially.

Size: Males, $9.7 \pm 0.20 \times 3.3 \pm 0.08$ mm (11). Females, $10.7 \pm 0.16 \times 3.6 \pm 0.06$ mm (19).

Male genitalia. (Fig. 1H). Parameres slightly diverging from basal piece, widened medially, rounded to apex. Median lobe pointed, sides acutely angled away. Apophysis of basal piece medium width, rounded apically.

Remarks. *C. indigohumerosa* sp.nov. is closest to *C. atricollis* (Saunders) (Fig. 1I), but male genitalia are narrower apically in *C. indigohumerosa* and the median lobe is sharp (blunt in *C. atricollis*). The head, pronotum and ventral surface of *C. atricollis* are dark. The distributions of *C. indigohumerosa* and *C. atricollis* do not overlap. Name derived from *indigo* L. 'blue', *humerus* L. 'shoulder'.

***Castiarina palliata* sp.nov.**

FIGS 1J, 4C

Holotype. ♂, Wilthorpe (mines), W.A., 6.x.1980, M. Powell, WAMA.

Allotype. ♀, same data as holotype, WAMA.

Paratypes. W.A.: 3 ♀♀, Port Samson, 2.ix.1967, F. H. Usher Baker, SAMA; 5 ♂♂, 5 ♀♀, same data as holotype, MPWA, SAMA; 1 ♂, 4 ♀♀, Fortescue Roadhouse, 23.viii.1987, M. Powell, MPWA; 2 ♂♂, 2 ♀♀, 132 km E Nanutarra, 29.vii.1988, MPWA.

Colour. Head dark blue. Antennae black with bronze reflections. Pronotum and scutellum black. Elytra orange with the following black markings: narrow basal margin; pre-medial fascia represented by a small spot on the suture and one on each elytron; post-medial fascia reaching margin, projecting anteriorly on suture and in middle of each elytron; mark covering apex in males, in most

females reduced to spade-shaped mark and around apical margin and spines. Fascia and apical mark connected along suture. Ventral surface dark blue. Legs dark blue, tips of tibia and tarsomeres with bronze-green reflections. Hairs silver.

Shape and sculpture. Head closely punctured, median sulcus, very short muzzle, eyes bulbous. Antennae compressed, antennomeres: 1-3 obconic; 4-11 toothed. Pronotum shallowly punctured laterally, sparsely punctured medially and slightly glabrous, basal notches represented by a glabrous area on each side more marginal than medial; apical margin projecting medially, basal margin bisinuate; laterally parallel-sided at base, rounded and narrowed to apex, widest anteromedially. Scutellum scutiform, punctured, glabrous, flat. Elytra punctate-striate, intervals convex, more so laterally and apically; laterally angled outwards from base,



Fig. 3. Habitus illustration of *Castiarina indigaventricosa* sp.nov.

rounded at humeral callus, concave, rounded posteromedially and narrowed to bispinose apex; large blunt marginal spine, very small sharp sutural spine, margin rounded and indented between spines, apices hardly diverging. Ventral surface with shallow punctures, edges of abdominal segments glabrous, sparse short hairs. *S.*: truncate in both sexes, slightly medially indented.

Size. Males, $11.9 \pm 0.19 \times 4.1 \pm 0.05$ mm (9). Females, $12.9 \pm 0.24 \times 4.5 \pm 0.10$ mm (15).

Male genitalia. (Fig. 1J). Parameres gradually diverging from base, rounded at apex. Median lobe pointed, sides acutely angled away. Basal piece medium width, rounded at apex.

Remarks. *C. palliata* sp.nov. is closest to *C. atricollis*. The pronotum, scutellum and elytral markings in *C. palliata* are black (dark blue in *C. atricollis*). Male genitalia differ (Figs 11, 13), those in *C. atricollis* being shorter and wider. The elytral colouring fades to pale yellow soon after death. The name is derived from *pallians* L. 'cloaked'.

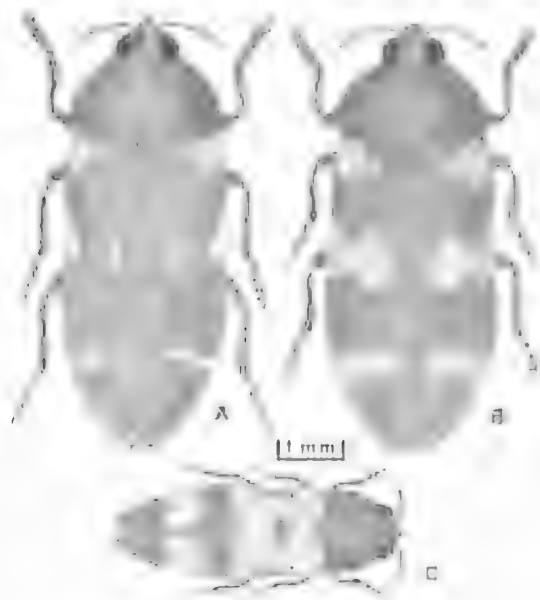


Fig. 4. Habitus illustrations of the following *Castiarina* species: A, *Castiarina daedalea* sp.nov. male, B, *C. daedalea* sp.nov. female, C, *C. palliata* sp.nov.

***Castiarina nota* sp.nov.**

FIGS 1K, 21

Holotype. ♂, 46 km SW Whyalla, S.Aust., 14.x.1989, S. Barker, SAMA I 21235.

Paratypes. S. Aust.: 3 ♂♂, 56 km E Kimba, 16.xi.1979, G. Harold, MHSA & ASSA; 1 ♂, 50 km NE Cowell, J.x.1982, S. Barker, SAMA; 1 ♂, 22 km E Kimba, 26.x.1982, S. Barker, SAMA; 1 ♂, 40 km NE Cowell, 14.x.1989, S. Barker; 1 ♂, Scrubby Peak, Gawler Ra., 4.xi.1989, S. Barker, SAMA; 1 ♂, Pinkawillinie C.P., 2.xi.1989, J. Bujega & A. Sundholm, ASSA.

Colour. Head bronze, muzzle blue. Antennae, antennomeres: 1-2 blue; 3-11 bronze. Pronotum bronze. Scutellum blue. Elytra orange with the following dark blue markings; narrow basal margin; elongate mark over each humeral callus; post-medial fascia usually reaching margin; pre-apical spade-shaped mark; mark along suture from scutellum to apices. All marks connected along suture. Ventral surface bronze. Legs; femora and

tibia blue; tarsomeres bronze-green. Hairs silver. **Shape and sculpture.** Head closely punctured, median sulcus, short muzzle. Antennae, antennomeres: 1-3 obconic; 4-11 toothed. Pronotum closely punctured, minute basal fovea extending forwards to middle as glabrous line; apical margin straight, basal margin bisinuate; laterally rounded from base to apex, widest posteromedially. Scutellum scutiform, glabrous, flat. Elytra punctate-striate, intervals convex more so laterally and apically than elsewhere, lightly punctured; laterally angled out from base, rounded at humeral callus, concave, rounded posteromedially and narrowed to bispinose apex; small sharp marginal spine, minute sutural spine, margin rounded and indented between spines, apices hardly diverging, apical margin subserrate. Ventral surface with shallow punctures, edges of abdominal segments glabrous, hairy, hairs medium length. S₁: male truncate and slightly indented medially; female unknown.

Size. Males, $11.6 \pm 0.25 \times 4.4 \pm 0.13$ mm (9).

Male genitalia. (Fig. 1K). Parameres diverging from basal piece, rounded to apex. Median lobe pointed, sides obtusely angled away. Apophysis of basal piece medium width, rounded apically.

Remarks. *C. nota* sp.nov. is closest to *C. crux* (Saunders). Male genitalia are narrower than in *C. crux* (Fig. 1L) in which the parameres are widened medially and broader apically. *C. crux* has blue markings on the elytra and is found in the Little Desert, Vic., whereas *C. nota* has dark blue markings and occurs on the Upper and Lower Eyre Peninsula, S.Aust. Named derived from *nota* L. 'mark or sign.'

***Castiarina indigoventricosu* sp.nov.**

FIGS 10, 3

Holotype ♂, Currarong, N.S.W., 3.i.1990, T. M. S. Hanton, SAMA I 21236.

Allotype. ♀, same data as holotype, SAMA I 21237.

Paratypes. N.S.W.: 11 ♂♂, 5 ♀♀, same data as holotype; 3 ♂♂, 4 ♀♀, Currarong, 15.i.1990, R. Mayo, RMNA; 6 ♂♂, 7 ♀♀, Currarong, 6.i.1990, A. Sundholm, ASSA.

Colour. Head blue. Antennae bronze. Pronotum, scutellum, ventral surface and legs blue. Elytra pale brown medially, yellow laterally with the following black markings; narrow basal margin; very narrow sutural margin; spines. Hairs silver.

Shape and sculpture. Head shallowly punctured, broad median sulcus, short muzzle. Antennae, antennomeres: 1-3 obconic; 4-11 toothed. Pronotum shallowly punctured, basal fovea extending to middle as glabrous line, basal notches

more marginal than medial; apical margin projecting medially, basal margin bisinuate; laterally parallel-sided at base, angled outwards, rounded to widest before middle, tapered to apex, dorso-ventrally flattened from base to middle. Scutellum scutiform, glabrous flat. Elytra punctate-striate, intervals convex and smooth; laterally angled out from base, rounded at humeral callus, concave, rounded posteromedially and narrowed to bispinose apex; long sharp marginal spine, smaller sutural spine, margin rounded and indented between, apices diverging. Ventral surface with shallow punctures, edges of abdominal segments glabrous, moderately hairy, hairs medium length. *S.*: males truncate; females truncate, medially indented.

Size. Males, $19.6 \pm 0.25 \times 7.5 \pm 0.11$ mm (21). Females, $20.7 \pm 0.35 \times 8.1 \pm 0.14$ mm (17).

Male genitalia. (Fig. 10). Heavily chitinized. Parameres parallel-sided from basal piece, pinched in, rounded premedially then parallel-sided, rounded to apex. Median lobe pointed, sides obtusely angled away. Apophysis of basal piece broad, apically rounded.

Remarks. *C. indigoventricosa* sp.nov. is closest to *C. jeanae* (Barker), but the colour of the head, pronotum and ventral surface is blue whereas it is usually green in *C. jeanae*; *C. indigoventricosa* occurs in coastal mallee heath in N.S.W., whereas *C. jeanae* is found in high altitude further inland. Male genitalia also differ (Figs 10, 1P) the parameres being broader medially in *C. jeanae*. The name is derived from *Indigo* L. 'blue', *venter* L. 'belly'.

Castiarina daedalea sp.nov.

FIGS 1Q, 4A, 4B

Holotype. ♂, Currarong, N.S.W., 6.i.1990, A. Sundholm, SAMA 21238.

Allotype. ♀, Currarong, N.S.W., 29.xii.1989, S. Lamond, SAMA 21239.

Paratype. N.S.W.: ♀, Currarong, 3.i.1990, T. M. S. Hanlon, MHSA.

Colour. Head, antennae, pronotum, grey-blue. Scutellum dark blue. Elytra red with the following dark blue markings: Female with basal margin narrow laterally, broad medially; broad pre-medial fascia reaching margin; broad post-medial fascia reaching margin; mark covering whole apex, all marks connected along suture. Male; the fascia are

coalesced leaving two red spots on the lateral margin and one medial but not touching suture and a narrow red pre-apical fascia. Ventral surface and legs dark blue. Hairs silver.

Shape and sculpture. Head closely punctured, median sulcus, muzzle medium length. Antennae, antennomeres: 1-3 obconic; 4-11 toothed. Pronotum closely punctured, basal fovea extending forwards to middle as glabrous line; apical margin projecting medially, basal margin barely bisinuate; laterally parallel-sided at base, rounded, widest posteromedially, tapered to apex; dorso-ventrally flattened from base to middle. Scutellum scutiform, glabrous, excavate. Elytra punctate-striate, intervals flat medially, convex basally, smooth; laterally angled out from base, rounded at humeral callus, concave, rounded posteromedially to bispinose apex; small marginal spine; small sutural spine, margin rounded and indented between, apices diverging, apical margin suberrate. Ventral surface with shallow punctures, edges of abdominal segments glabrous, moderately hairy, hairs long. *S.*: truncate both sexes.

Size. Male, 17.7×7.0 mm (1). Females, $17.4 \pm 0.58 \times 7.1 \pm 0.21$ mm (2).

Male genitalia. (Fig. 1Q). Parameres parallel-sided at base, gradually widened posteromedially, rounded at apex. Median lobe pointed, sides obtusely angled away. Apophysis of basal piece medium width, rounded at apex.

Remarks. *C. daedalea* sp.nov. does not closely resemble any other described species. The name is derived from *daedalus* L. 'skillfully made in the manner of Daedalus, the Athenian artificer.'

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MAGNOBATES (ACARIDA: CRYPTOSTIGMATA: HAPLOZETIDAE) FROM SOUTH AUSTRALIAN SOILS

BY DAVID C. LEE & KEREN J. SHEPHERD*

Summary

Magnobates Hammer, 1967 is redefined to include two species previously grouped in *Lauritzenia* Hammer 1958. Two new species, from soil and litter in savannah woodland and sclerophyll forest, are described: *M. elongatus* sp. nov., *M. globulus* sp. nov. They do not occur in drier South Australian sites. Relationships between some genera of Haplozetidae Grandjean, 1936 are discussed. A key to adults is given for the five species of *Magnobates*: this is its first record from Australia.

KEY WORDS: *Magnobates elongatus* sp. nov., *M. globulus* sp. nov., *Lauritzenia* Hammer, Haplozetidae, Acarida, soils, South Australia.

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Summary

LEE, D. C. & SHEPHERD, K. J. (1990) *Magnobates* (Acarida: Cryptostigmata: Haplozetidae) from South Australian soils. *Trans. R. Soc. S. Aust.* 114(4), 179-186, 30 November, 1990.

Magnobates Hammer, 1967 is redefined to include two species previously grouped in *Lauritzenia* Hammer, 1958. Two new species, from soil and litter in savannah woodland and sclerophyll forest, are described: *M. elongatus* sp. nov., *M. globulus* sp. nov. They do not occur in drier South Australian sites. Relationships between some genera of Haplozetidae Grandjean, 1936 are discussed. A key to adults is given for the five species of *Magnobates*; this is its first record from Australia.

KEY WORDS: *Magnobates elongatus* sp. nov., *M. globulus* sp. nov., *Lauritzenia* Hammer, Haplozetidae, Acarida, soils, South Australia.

Introduction

The genus *Magnobates* Hammer, 1967 is examined as part of an ongoing study of sarcoptiform mites in South Australian soils, sampled from nine florally diverse sites. An introduction to the relevant work on the advanced oribatid mites (Planofissurac) is provided by Lee (1987).

Magnobates appears to be closely allied to *Haplozetes* Willmann, 1935 and *Lauritzenia* Hammer, 1958 in the Haplozetidae Grandjean, 1936. Examination of the holotypes of the type-species of *Magnobates* and *Lauritzenia*, and consideration of the thorough redescription of the type-species of *Haplozetes* (*H. vindobonensis* Willmann, 1935) by Grandjean, 1936, substantiates this relationship. The delineation of *Magnobates* from *Lauritzenia* is considered, resulting in two species being newly combined with *Magnobates*. New species are recognised and described from the South Australian material.

Materials and Methods

New material examined here, collected by D.C.L., is mainly deposited in the South Australian Museum (SAMA), but also in the Natural History Museum, London (BMNH), the Field Museum, Chicago (FMNH) and the New Zealand Arthropod Collection, D.S.I.R., Auckland (NZAC). Established types examined are deposited in the Zoological Museum, Copenhagen.

No new notational systems are introduced. All measurements are in micrometres (μm) and were

made using an eyepiece micrometer at $\times 250$ magnification.

Systematics

Family: Haplozetidae Grandjean, 1936

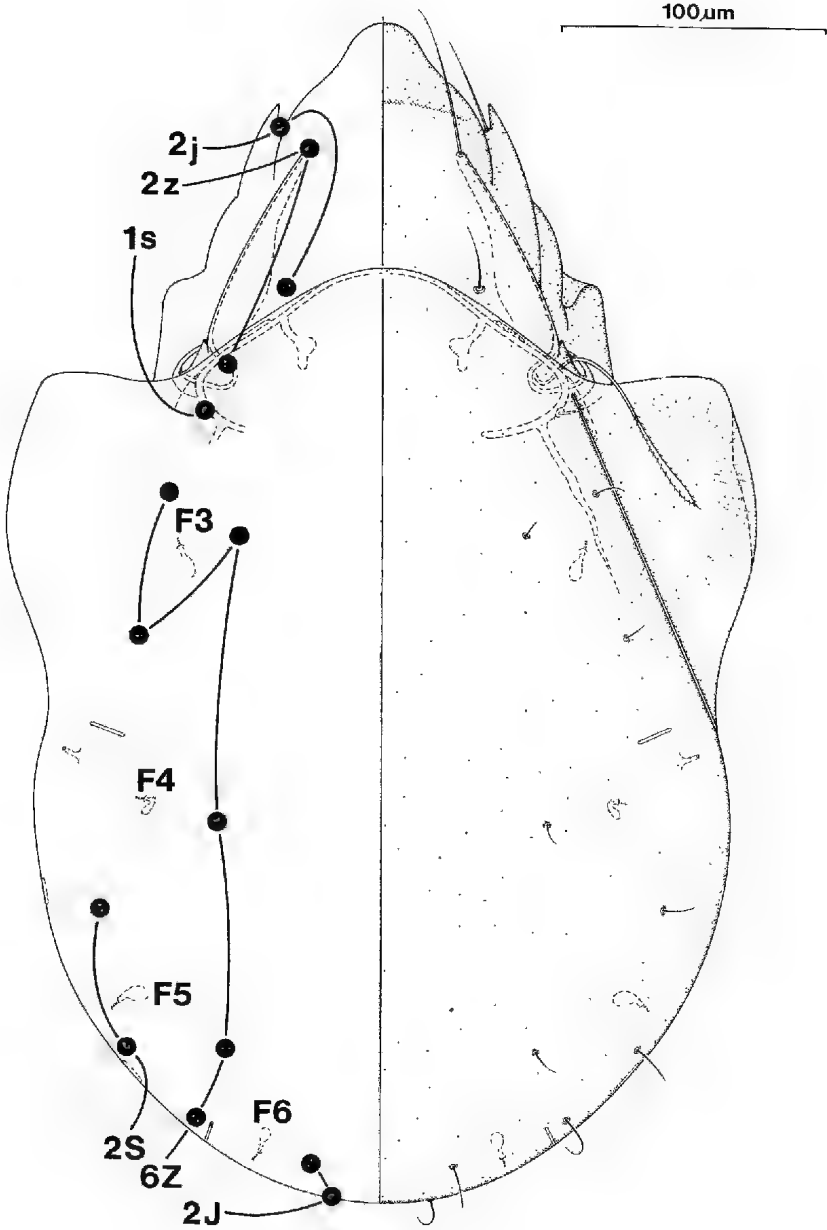
Discussion: The Haplozetidae comprised oripodoid genera with hinged pteromorphs. Balogh & Balogh (1984) further restricted the family to 18 genera with sacculate hysteronotal foramina, and recognised four subfamilies on the basis of the number of genital setae. This definition of subfamilies, however, is not consistent with all species within the genera *Haplozetes* Willmann, and *Lauritzenia* Hammer. Further, the keys provided by Balogh & Balogh (1984) are inconsistent in their treatment of pretarsal claws. *Haplozetes* and *Lauritzenia* are considered to be monodactyl, although some species of these genera have three pretarsal claws. These authors excluded *Magnobates* from the Oripodoidea without justification.

The new material examined here has three pretarsal claws and keys to *Incabates* by Balogh & Balogh's (1984) criteria. However, they differ from *Incabates* by the discidium being quadrangulate rather than triangulate, the proteronotal seta $\alpha 1$ being lateral to seta $\alpha 1$ rather than in front of it, and the tuforium being laminar with a projecting anterior cusp rather than costate and without a cusp.

These character states of the new species are shared with *Haplozetes*, *Lauritzenia* and *Magnobates*, which are here regarded as an unnamed monophyletic group. They also share this group's synapomorphy of a hysteronotal foramen with a narrow refractile section of the duct near to its pore in the integument, usually accompanied by

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a hemispherical refractile plate. This is illustrated for *Haplozetes* by Beck (1964) and Grandjean (1936), and newly established as present on the holotype of the type species of *Lauritzenia* and *Magnobates* (*L. longipluma* Hammer, 1958 & *M. flagellifer* Hammer, 1967). It is further established that these two type species are similar to the new *Magnobates* species in having a long curved alveolus with the somal setal pores, three setae on genu II (v present) and a subrectangular discidium.

The reliable delineation of the three genera requires a thorough revision of the cosmopolitan *Haplozetes*, which may have four or five genital setae and one or three pretarsal claws. Initially, I here distinguish the two genera confined to southern temperate regions from *Haplozetes* by the presence of three setae on genu II, and from each other by the number of pretarsal claws (*Lauritzenia* with one claw, *Magnobates* with three claws). This requires the transfer of two species from *Lauritzenia*, as indicated in the remarks on *Magnobates*, leaving *Lauritzenia* (from South America) as monotypic.

Magnobates Hammer

Magnobates Hammer, 1967, p. 30 (type species by monotypy: *Magnobates flagellifer* Hammer, 1967); Hammer 1968, p. 72; Balogh 1972, p. 169; Luxton 1985, p. 63.

Lauritzenia Hammer, 1958 (part); Hammer 1968, p. 70.

Definition: Hysteronotum with 10 pairs (2I, 6Z, 2S) of setae and four pairs of normal (not fissuriform) sacculate foramina. Hysteronotal foramina with long, tubular sacculi and short, narrow refractile duct near integument, convex refractile hemispherical structure between these. Dorsosejugal furrow entire. Translamella and prelamella absent, conspicuous laminar tutorium (between setae jI-j2). Rostral seta (jI) transposed laterally, beside rather than in front of seta zI. Pteromorph movable, with clear weakly sclerotized basal line. Discidium subrectangular, without custodium. Tibia I with large solenidium (so2) on nearly flat dorsal surface, not tubercle, solenidium sol may or may not be on spur-like distodorsal tubercle. Tibia II with distodorsal spur. Genu II with three setae (v present). Tracheanter IV with distodorsal angle rounded and ridged, distoventral crown with only anterior angulate lobe, broad flange extending along entire venter of caput. Pretarsus with three claws, slimmer lateral claws with either ventral subterminal tooth or truncated tip.

General Morphology: Somal length range for adults: 330-1030. Somal chaetotaxy: 2j, 2z, 1s; 2I, 6Z, 2S; 3I, III, 3III, usually 3 (rarely 2) IV; usually 4 (rarely 5 or 6) JZg, 1Sg; 2JZu, 3Su. Leg chaetotaxy (solenidia in parentheses): I — 1, 5, 3 (1), 4 (2), 20 (2); II — 1, 5, 3 (1), 4 (1), usually 16 (rarely 15) (2); III — 2, 3, 1 (1), 3 (1), 15; IV — 1, 2, 2, 3 (1), 12. Alveolar canal of somal setae usually dilated and long, narrowing at internal extremity to refractile ring, sometimes twisted up to near cuticle, appearing like pore and sacculus near setal base, as described on *Magnobates acutirostrum* (Hammer, 1968) and *M. rotundirostrum* (Hammer, 1968). Pteromorph may lie close to the pleural surface (Fig. 6) or be lifted away from it (Fig. 5). Sub-bothridial flange present. Apodemes I, II, ventrosejugal and III present, with wide midsternal gap (greater than width of genital orifice) in ventrosejugal apodeme. Subpedal and circumpedial ridges merging into single continuous line. Proximoventral spur on tibiae I and II and distodorsal spur on tibia II. Femur I without caput collar. Conspicuous ventral flanges on femurs II and IV, on femur II margin angulate enclosing right angle.

Distribution: Australia (Aa) and New Zealand (An). The three species from New Zealand were either from lawn moss, a rotten branch or tree bark in the north of North Island, whilst in South Australia *Magnobates* was only recorded from the two moister sites that are in the savanna woodland and dry sclerophyll forest of the Mt Lofty Ranges. Within Australia, *Magnobates* may prove to be confined to the moister southern temperate regions.

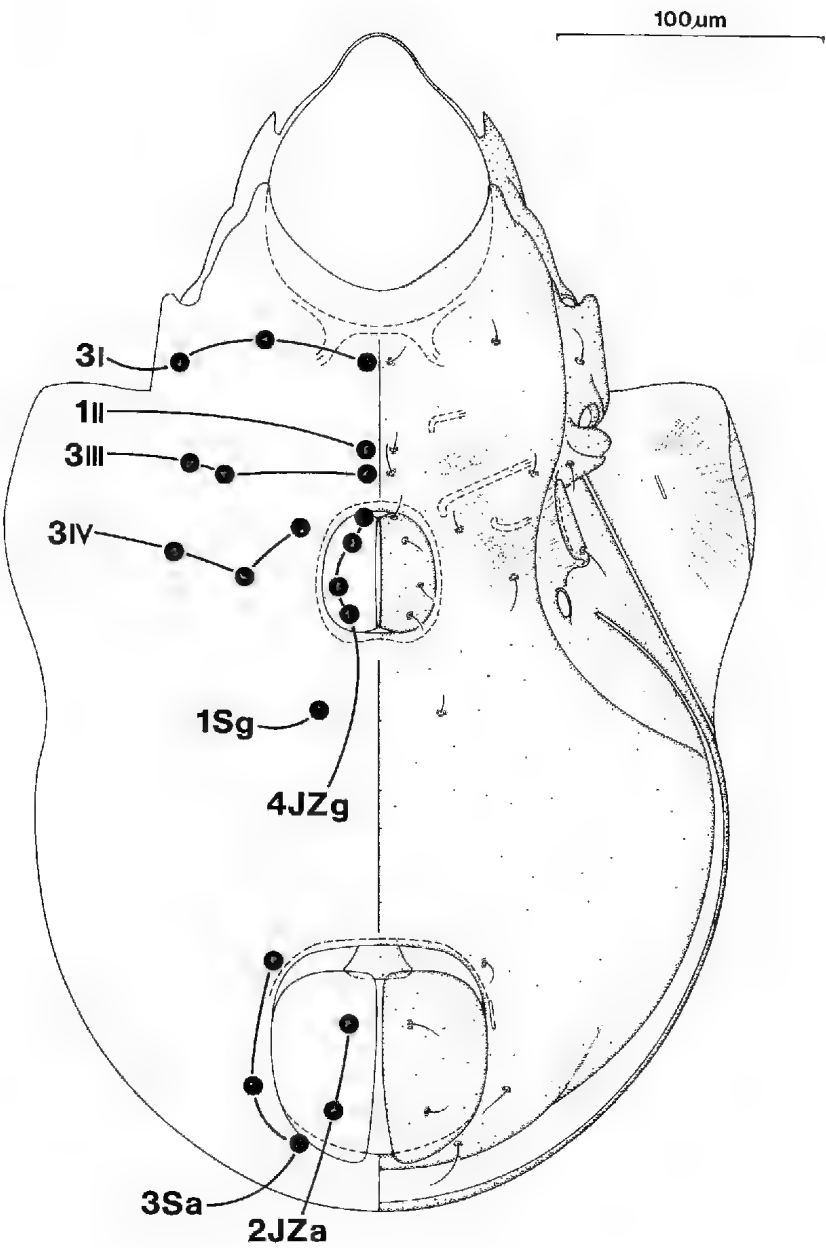
Remarks: *Magnobates* was included in the Ceratozetoidea when it was established, but the placing by Balogh (1972) and Luxton (1985) in the Haplozetidae Grandjean, 1936 is followed with confidence, since *Magnobates* is very similar to *Haplozetes*, as already indicated here. Although *Magnobates* may prove to be a synonym of *Lauritzenia*, it is retained, using the only distinguishing character available, the number of pretarsal claws. This requires two species to be moved from *Lauritzenia* to be combined as in the list of *Magnobates* species. *Magnobates* includes five species as follows: *M. acutirostrum* (Hammer, 1968) comb. nov., *M. elongatus* sp. nov., *M. flagellifer* Hammer, 1967, *M. globulus* sp. nov., *M. rotundirostrum* (Hammer, 1968) comb. nov.

Key to *Magnobates* species (adults)

- 1 — Five or six pairs of genital setae (5 or 6/JZg). Lamella wide, dorsally obscures tutorium

Fig. 1. *Magnobates elongatus* sp. nov. female, notum and soma.

2



- behind seta $z1$2
- Four pairs of genital setae (4JZg) Lamella medium width, dorsally obscures tumidium only behind seta $j2$3
 - 2 - Soma longer than 600 μm . Soma setae long (Z4 reaches S5, Sg longer than $0.5 \times$ genital shield).....*M. rotundirostrum* (Hammer)
 - Soma shorter than 500 μm . Soma setae medium length (Z4 reaches halfway to S5, Sg shorter than $0.5 \times$ genital shield).....*M. acutirostrum* (Hammer)
 - 3 - Soma longer than 900 μm . Sensory proteronotal seta $z2$ tapering without caput.....*M. flagellifer* (Hammer)
 - Soma shorter than 500 μm . Sensory proteronotal seta $z2$ with weakly swollen fusiform caput.....4
 - 4 - Sensory proteronotal seta $z2$ with slim caput (greatest width less than $3 \times$ stalk width). Hysteronotal foramen F5 with spherical saccule. On tibia I, solenidium sol distal to $so2$ and on tubercle.....*M. elongatus* sp. nov.
 - Sensory proteronotal seta $z2$ with medium width caput (greatest width more than $4 \times$ stalk width). Hysteronotal foramen F5 with T-shaped saccule. On tibia I, solenidium sol level with $so2$ and not on tubercle.....*M. globulus* sp. nov.

***Magnobates elongatus* sp. nov.**

FIGS 1-3

Type material: Holotype female (SAMA N1990242), plant litter, sparse moss and sandy soil, under sclerophyllous shrubs amongst mesquite stringybark (*Eucalyptus obliqua*), dry sclerophyll forest, near summit of Mt Lofty (34°59'S, 138°45'E), Cleland Conservation Park, 9.v.1974. Paratypes, eleven females (SAMA N1990243 - N1990250, 1-BMNH, 1-FMNH, 1-NZAC) and thirteen paratype males (SAMA N1990251 - N1990260, 1-BMNH, 1-FMNH, 1-NZAC), as holotype.

Female: Idiosomal length, 423, (12, 401-437). Leg lengths (femur-tarsus for 434): I-204, III-175, II-161, IV-205. Tibial maximum heights (for 434): I-22, II-17, III-17, IV-17.

Proteronotum with lamellar margin straight, sub-linear. Bothridium (base of seta $z2$) with normal,

short (less than $0.5 \times$ diameter of aperture) anterior process and small sub-bothridial flap. Seta $j1$, $j2$ and $z1$ smooth and slim, $j2$ subequal in size to Z6. Sensory seta $z2$ with slim fusiform caput, greatest width less than $3 \times$ width of stalk. Hysteronotum with some very short setae (Z2, Z3, Z4), not as long as fissure-like pore $h/3$. Foramina with globular saccules at end of short tubular ducts.

Idiosternal setae smooth, slim and short, $I3$ and $Sa3$ longest, seta $III3$ longer than $III2$, and $IV3$ present. Pedotectum II rounded distally, ventral ridge reaches posterior margin to form spur. No eggs observed.

Legs short (mean femur-tarsus length: 43% of somal length). On tibia I, solenidium sol nearly directly distal to $so2$ and on distodorsal spur-like tubercle. Flange on femur I and II slightly bigger, and on trochanter IV slightly smaller, than on *Magnobates globulus*.

Male: Similar to female but idiosoma shorter, mean length, 392 (sclerophyll forest, 13, 380-403), 411.5 (savannah woodland, 1).

Referred material: Undesignated male (SAMA N1990261), grass, moss, leaf litter and loamy soil under manna gum trees (*Eucalyptus viminalis*), savannah woodland, Chambers Gully (34°58'S, 138°41'E), Cleland Conservation Park, 12.vi.1974.

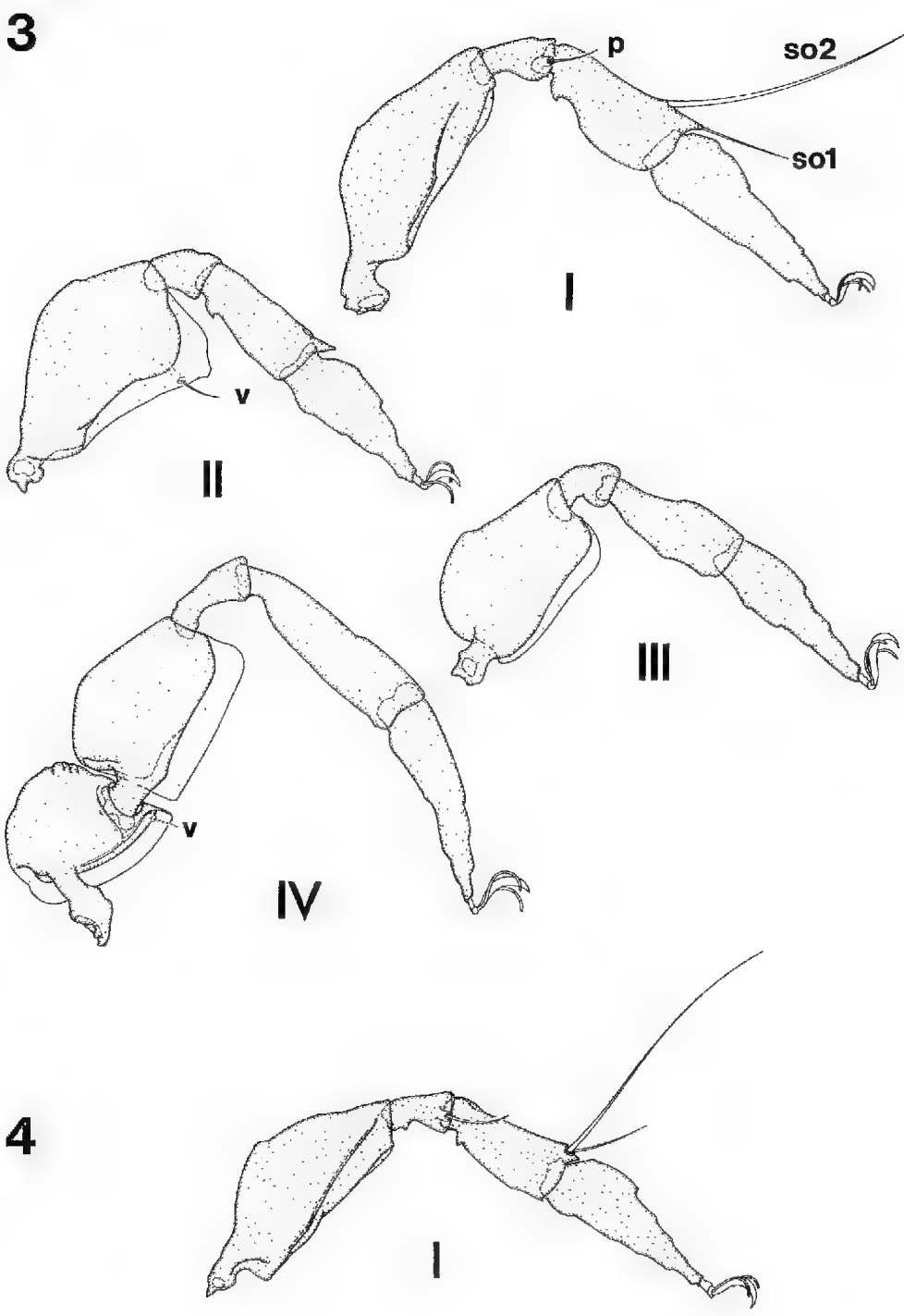
Remarks: The specific name *elongatus* is derived from the Latin 'prolonged' and refers to its idiosomal shape (when pteromorphs folded down) compared with *M. globulus*. It can be distinguished from the smaller two New Zealand species (*M. acutirostrum* and *M. rotundirostrum*) by having fewer genital setae, a narrower lamella and slim smooth proteronotal setae and from *M. flagellifer* by being smaller. The slimness of the proteronotal setae and shortness of seta $j2$ is unique within *Magnobates*, but a short seta $j2$ is found on *Lauritzenia longiphuma* Hammer, 1958, which also has solenidium sol of tibia I on a dorsodistal tubercle.

***Magnobates globulus* sp. nov.**

FIGS 4-6

Type Material: Holotype, female (SAMA N1990262), grass, moss, leaf litter and loamy soil under manna gum trees (*Eucalyptus viminalis*), savannah woodland, Chambers Gully (34°58'S, 138°41'E), Cleland Conservation Park, 12.vi.1974. Paratypes, two females (SAMA N1990263, N1990264) and one male (SAMA N1990265), as holotype.

Fig. 2. *Magnobates elongatus* sp. nov., female, sternum of soma.



100µm 3 4

Female: Idiosomal length, 341 (3, 336–347). Leg lengths (femur-tarsus for 336: I–167, II–149, III–145, IV–176. Tibial maximum heights (for 336): I–17, II–13, III–12, IV–13.

Proteronotum with lamellar margin curved, convex. Bothridium (base of seta z2) with long (as long as diameter of aperture) anterior process and large sub-bothridial flap. Setae j1, j2 and z1 ciliate and stout, j2 unlike Z6. Sensory seta z2 with robust clavate caput, greatest width more than 4 × width of stalk. Hysteronotal setae short but all longer than fissure-like pore h/3. Foramina with small globular saccules at end of ducts, except F5 where saccule T-shaped.

Idiosternal setae often smooth, slim and short, but midsternal coxite setae (files 1 and 2) stouter and clearly ciliate, and III and IIII as long as or longer than I3 and Sz3. Setae III3 shorter than all others, IV3 absent. Pedotectum II flat distally, ventral ridge not forming spur on posterior margin. Eggs ellipsoidal, exochorion smooth, 129 × 86–136 × 57 (for 337 only, other two females without eggs).

Legs medium-length (mean femur-tarsus: 47% of somal length) and tibiae medium-height (mean maximum height: 36% of mean length). On tibia I, solenidium sol nearly directly in front of so2, both on flat dorsal surface, not on spur. Flanges on femur I and III slightly smaller, and on trochanter IV slightly bigger, than on *Magnobates elongatus*.

Male: Similar to female but idiosoma shorter, 332.

Remarks: The specific name *globulus* is derived from the Latin for 'bead' or 'small ball', referring to its globular shape when its pteromorphs are folded down, unlike *M. elongatus*. It is the smallest known species of *Magnobates*. The globular shape and the stouter ciliate proteronotal setae are similar to those of *M. acutirostrum*, *M. flagellifer* and *M. rotundirostrum*, and these character states may be primitive. The disposition of the solenidia on tibia I also is common within the Oripodoidea. The unusual T-shaped saccule of foramen F5 is unique within *Magnobates*, but is similar to that of *Lauritzenia longipluma* Hammer, 1958 and some species of *Haplozetes* (Beck 1964; Grandjean 1936).

Acknowledgments

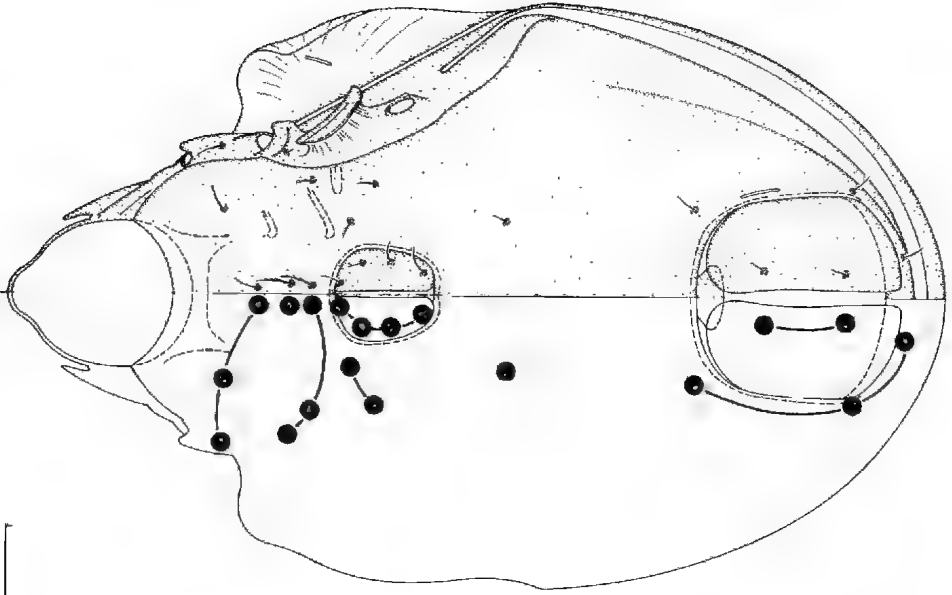
We are indebted to the Australian Biological Resources Study for funding the salary of K.J.S. in a grant to D.C.L., as well as to Dr Henrik Enghoff (Zoological Museum, Copenhagen) for making two types available. Thanks are also due to Ms Kirstie Jamieson for the notation and presentation of the figures and Mrs Debbie Lowery for typing the manuscript.

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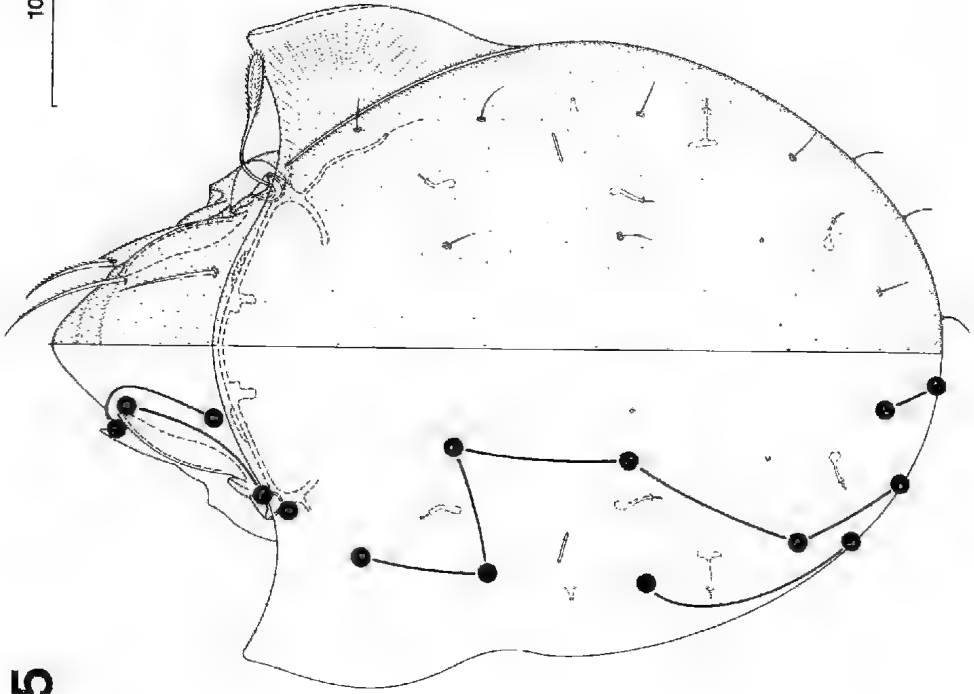
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Figs 3–4. *Magnobates*, posterior aspect of right legs. 3, *M. elongatus* sp. nov., legs I–III (femur-pretarsus), leg IV (trochanter-pretarsus); 4, *M. globulus* sp. nov., leg I (femur-pretarsus). Only setae represented are posterior seta on genu I, two solenidia on tarsus I, ventral seta on femora II (only seta v2), IV and trochanter IV.

6



5



Figs 5-6. *Magnobates globulus* sp. nov., female. 5, notum of soma; 6, sternum of soma.

RHEOBATRACHUS LIEM AND TAUDACTYLUS STRAUGHAN & LEE (ANURA: LEPTODACTYLIDAE) IN EUNGELLA NATIONAL PARK, QUEENSLAND: DISTRIBUTION AND DECLINE

*BY KEITH R. McDONALD**

Summary

Rheobatrachus vitellinus Mahony, Tyler & Davies disappeared from monitored sites in the Clarke Range, Eungella National Park, Queensland within 17 months of its discovery in January 1984. The frog was confined to rainforest streams above 405 m in shallow, rocky, broken-water areas, in cascades, riffles and trickles - but was absent from pools of water found between riffles. Its former distribution within this system is reported. The associated stream-dwelling species *Taudactylus eungellensis* Liem & Hosmer also declined and disappeared from these and other sites during this period. *T. liemi* Ingram found in seepage areas adjacent to the same streams is still present in its preferred habitat. The decline of *R. vitellinus* and *T. eungellensis* closely parallels that of *R. silus* and *T. diurnus* in southeastern Queensland. Causes of these declines have not been determined, but many be manifestations of natural population fluctuations of large amplitude.

KEY WORDS: *Rheobatrachus*, *Taudactylus*, Eungella, population decline, distribution, frogs.

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Rheobatrachus vitellinus Mahony, Tyler & Davies disappeared from monitored sites in the Clarke Range, Eungella National Park, Queensland within 17 months of its discovery in January 1984. The frog was confined to rainforest streams above 405 m in shallow, rocky, broken-water areas, in cascades, riffles and trickles — but was absent from pools of water found between riffles. Its former distribution within this system is reported. The associated stream-dwelling species *Taudactylus eungellensis* Liem & Hosmer also declined and disappeared from these and other sites during this period. *T. hemi* Ingram found in keepage areas adjacent to the same streams is still present in its preferred habitat. The decline of *R. vitellinus* and *T. eungellensis* closely parallels that of *R. silus* and *T. diurnus* in southeastern Queensland. Causes of these declines have not been determined, but may be manifestations of natural population fluctuations of large amplitude.

KEY WORDS *Rheobatrachus*, *Taudactylus*, Eungella, population decline, distribution, frogs.

Introduction

Eungella National Park, situated in the Clarke Range west of Mackay, Queensland, comprises 49,610 hectares including most of the rainforest found in this district. The area supports a number of endemic species of birds, reptiles and frogs (Winter & McDonald 1986). Among the frogs are the gastric brooding frog *Rheobatrachus vitellinus* Mahony, Tyler & Davies and the torrent-adapted 'day frogs', *Taudactylus eungellensis* Liem & Hosmer and *T. liemi* Ingram. These relatively new additions to the frog fauna of Australia have close relatives in southeastern Queensland, namely *R. silus* Liem and *T. diurnus* Straughan & Lee.

The gastric brooding frogs *R. silus* and *R. vitellinus* have attracted considerable interest because of their bizarre habit of brooding their young in the stomach and oral birth (Corben, *et al.* 1974; Tyler 1983; McDonald & Tyler 1984; Leong *et al.* 1986). Inexplicably, *R. silus* disappeared throughout its range in southeast Queensland (Ingram 1983; Czechura 1984; Tyler & Davies 1985) and has not been seen in the wild since 1981. Paralleling this disappearance has been the decline and disappearance across its range of the day frog *Taudactylus diurnus*, a common co-inhabitant of streams with *R. silus*, and known also from other localities (Czechura 1984).

The discovery of *R. vitellinus* by Mahony in January 1984 (Mahony *et al.* 1984), provided an opportunity to further study this unusual genus. A monitoring programme was instituted by the Queensland National Parks & Wildlife Service to obtain data on distribution patterns and seasonal information. Here I report the former distribution of *R. vitellinus* within Eungella National Park and detail its decline and disappearance from monitored sites (Winter & McDonald 1986). I also provide information on the distribution, decline and disappearance of the associated stream dwelling species, *T. eungellensis* (Winter & McDonald 1986).

Materials and Methods

Distribution data for *R. vitellinus* were obtained by searching creeks on the Clarke Range at night using headlights, and during the day by looking under rocks and vegetation in the creeks. The presence or absence of *T. eungellensis* and *T. hemi* was also documented. Visits of two to five days were made once a month from January 1984–March 1985, from June–October 1985 and every second month from December 1985–February 1987. After this period, visits were spaced at once every three months until March 1989. No other visits were made until the last visit reported in this paper in March 1990.

Localities were searched and recorded for presence or absence of frogs. The altitude was measured to 5 m using an altimeter. Frogs were

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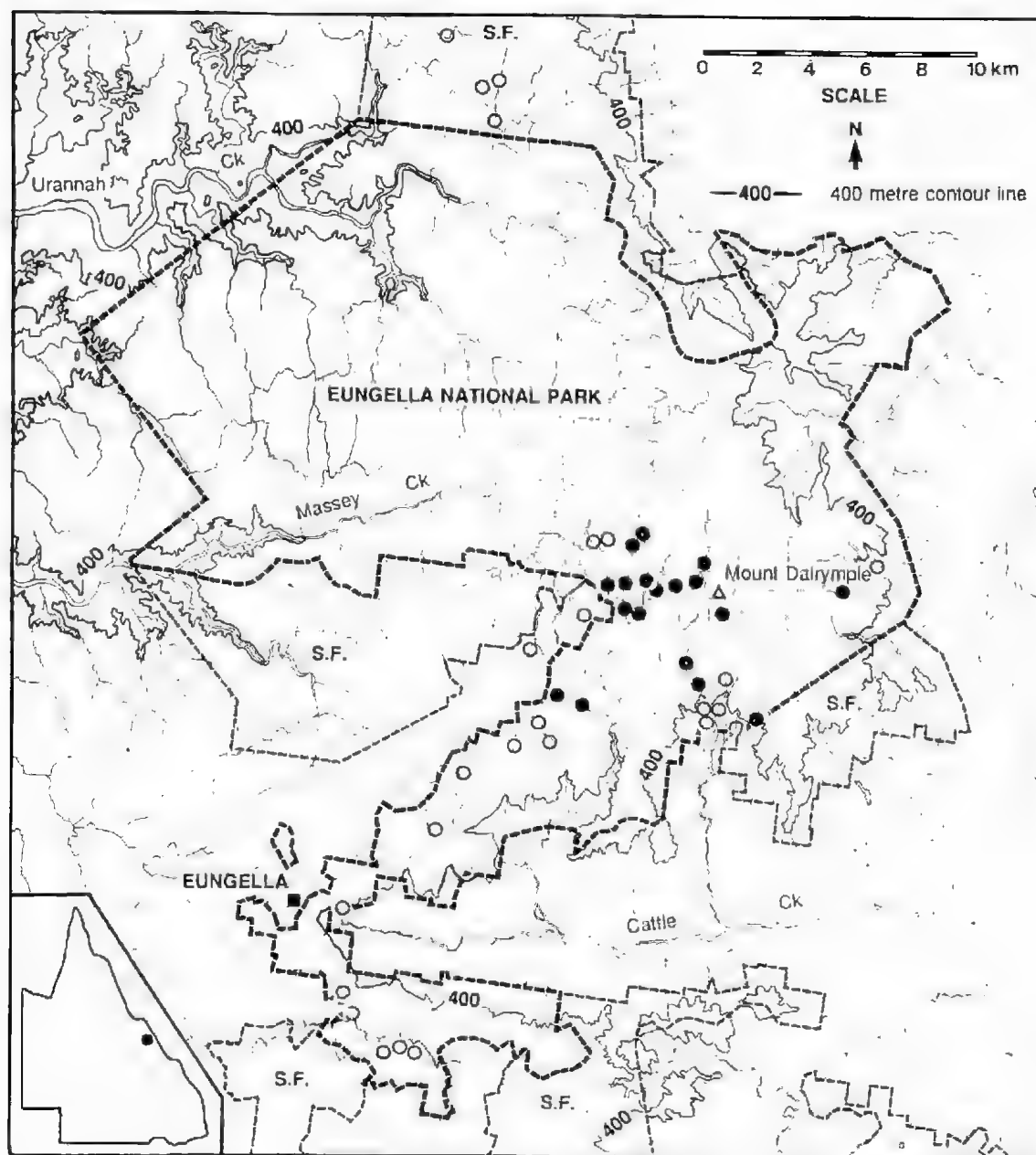


Fig. 1. Distribution of *Rheobatrachus vitellinus* in Eungella National Park to January 1985. Closed circles indicate sites at which frogs were located; open circles indicate sites searched, but in which frogs were not found. Triangle indicates Mt Dalrymple. S.F. = State Forest.

weighed to ± 0.5 g using a Persola spring balance and snout to vent lengths (SVL) were measured using dial calipers, recognising the inherent inaccuracy of ± 3 mm in measuring live animals (Ingram 1983). All animals were sexed, where possible, and recorded as male, female or subadult. Samples were measured from the same locality in late winter 1984 through to autumn 1985 on the following dates: 24 August, 17–18 September, 16–19, 22 and 26 October, 19–20 November, 6, 8, 19 December, 4–6, 22 January and 8–9 March. Other biological information (habitat selection, diet etc.) is the subject of a further paper (McDonald in prep.). Rainfall data (1939–1989) for Dalrymple Heights (= Eungella township) were collated. Regression analyses were performed using the SASTAT package of Wilkinson (1986).

Results

Distribution data for *Rheobatrachus vitellinus* and *Taudactylus eungellensis* are provided in Figs 1 and 2. *R. vitellinus* was recorded in rainforest streams above 405 m. These were order 1–3 streams (Chorley 1969), and animals were located in shallow, rocky, broken-water areas, in cascades, riffles and trickles, but were absent from the pools of water found between riffles. It was not unusual to locate up to six frogs in an area 2×5 m in the riffle. During rain, the frogs were frequently on rocks and easily distinguished in the headlight.

The recorded distribution of *R. vitellinus* is in undisturbed rainforest. No logging, clearing or mining has taken place; the only human disturbance is a poorly defined walking trail through part of the area. Streams above 400 m in which *R. vitellinus* was not located had shallow gradients. *Mixophyes fasciolatus*, *Litoria chloris* and *Adelotus brevis* were found in the streams, but their preferred habitat was backwaters or pools in the rocks. *L. lesueuri* was not found in the same area as *R. vitellinus* but was present in some habitats of *T. eungellensis*.

Taudactylus eungellensis was found above 150 m in the same area as *R. vitellinus* as well as in the rainforest areas to the north and south (Fig. 2). It was present also in logged rainforest. Frogs were active in waterfall and riffle splash zones during the day and it was not unusual to see five or more in an area 1×2 m on rocks in riffle areas and in a similar density in splash zones near waterfalls.

T. liemi was found in seepage areas adjacent to the streams in which the other two species were found or in areas where streams were not flowing above the ground. *T. liemi* and *T. eungellensis* laid eggs in the same water.

Both *R. vitellinus* and *T. eungellensis* were considered common across the range (as defined by Kirkpatrick & Lavery 1979) until January 1985 when the first signs of the decline (reported by Winter & McDonald 1986) was observed at lower altitudes (i.e. about 400 m). At higher altitude the frogs were common until March 1985 but were absent in June of that year.

R. vitellinus has not been recorded from monitored or any other sites within Eungella National Park since March 1985. A small population of *T. eungellensis* was recorded in the southern area of its distribution (see location A on Fig. 2) in June 1986, but disappeared after that date.

Tadpoles of *T. eungellensis* disappeared from areas being monitored for *R. vitellinus* but were present in the southern areas of the distribution of *T. eungellensis* until May 1987. Tadpoles suspected to be those of *T. liemi* were found in small pools in September 1987 in the streams flowing from the southern end of Mt David (Fig. 2 site B). Tadpoles of *Taudactylus* disappeared from the monitored stream sites by January 1988.

Potential or actual predators, although not quantitatively assessed, did not appear to change in numbers before and after the disappearance of the frogs. These included eels (*Anguilla reinhardtii*), water rats (*Hydromys chrysogaster*), snakes (*Pseudechis porphyriacus*, *Cacophis squamulosus*, *Cryptophis nigrescens*) and crayfish (*Euastacus eungella*). A crayfish was observed on 9.iii.1985 with the right leg of an individual of *R. vitellinus* in its chela.

Rainfall data for the period 1939–1989 are provided in Fig. 3 and monthly rainfall records from 1980–1989 in Fig. 4. At all times during the period of monitoring, order 2 & 3 streams continued to flow.

The relationship between SVL and weight for males, females and subadults of *R. vitellinus* between August 1984 and March 1985 is shown in Fig. 5. Regression lines and confidence limits for males and females only are shown in Fig. 6. Further statistical analysis was not employed because of small sample sizes.

Discussion

A number of factors might have contributed to the decline of *Rheobatrachus vitellinus* and *Taudactylus eungellensis*.

Ingram (1983) experienced difficulty in locating *R. silus* in the winter months and suggested that the species may shelter or hibernate, although he had no direct evidence of such an occurrence. *R.*

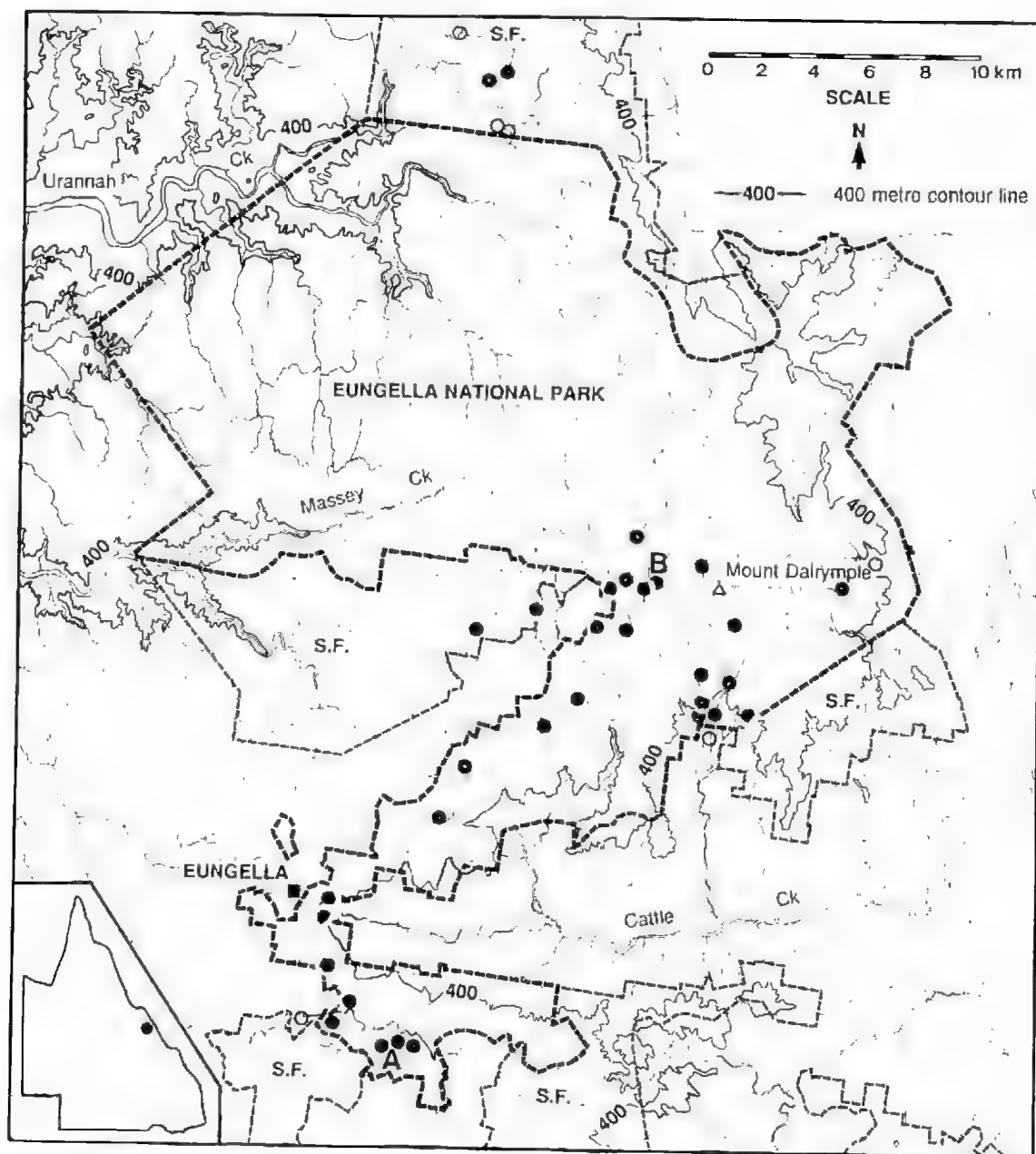


Fig. 2. Distribution of *Taudactylus eungellensis* in Eungella National Park to January 1985. Closed Circles indicate sites at which frogs were located; open circles indicate sites searched but in which frogs were not found. Site A is the site at which the species was last recorded in June 1986 and Site B is where the last *Taudactylus* tadpoles were recorded.

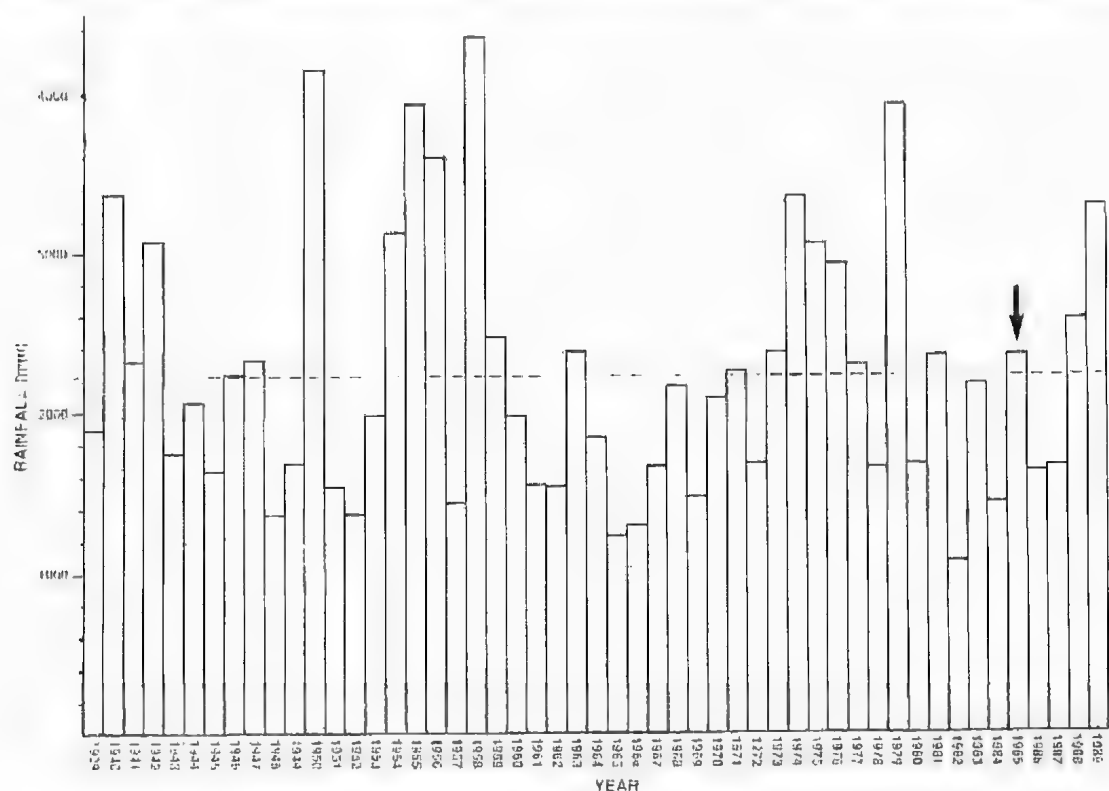


Fig. 3. Rainfall data for Dalrymple Heights (= Eungella Township) for the period 1939 (when records commenced) — December 1989. Mean annual rainfall indicated by dashed lines.

vitellinus, on the other hand, was abundant during the winter of 1984, hence a decline in the winter of 1985 cannot be attributed to seasonal behaviour.

Rainfall at the time of the decline was average (Fig. 3, amplified in Fig. 4). During the monitoring period, none of the order 2 and 3 streams dried up. Low average rainfall occurred in 1971, 1978, 1982 (drought) and 1984. During this time *T. eungellensis* was recorded commonly in the area (unpubl. data). *R. vitellinus* was first collected in January 1984. These data suggest that climatic change as represented by rainfall and stream flow was not a factor contributing to species decline.

No obvious man-made disturbance can be associated with the disappearance. Twenty-two specimens are known to have been collected for scientific purposes (unpubl. data) over a period of 15 months (January 1984–March 1985) and from a range of localities. At the time of collection, the species was abundant at each site and it is extremely unlikely that collection had an impact on numbers. Eleven *T. eungellensis* were collected during the same time period.

If the animals had been disturbed by the data collection or had been affected by disease, heavy parasite loads or some such adverse factor, a deterioration in body condition would have been expected. This could have shown in the relationship between weight and snout vent length over time. By inspection, Fig. 5, which combines data from male, female and subadult individuals, does not indicate such a trend. Regression analysis of the data by sex (subadult individuals were not considered as the sex was indeterminate) indicates, if anything, an improvement over time, but very little importance can be attached to this because of the small sample size.

T. liemi inhabits seepages and appears not to have been affected by factors contributing to the decline of stream dwelling *T. eungellensis* and *R. vitellinus*. Nevertheless a decline in *Adelotis brevis* which inhabits backwaters and pools may be occurring. The species has been heard calling only once (January 1986) in the former distribution of *R. vitellinus* since the latter disappeared but was still present in the southern part of the range of *T.*

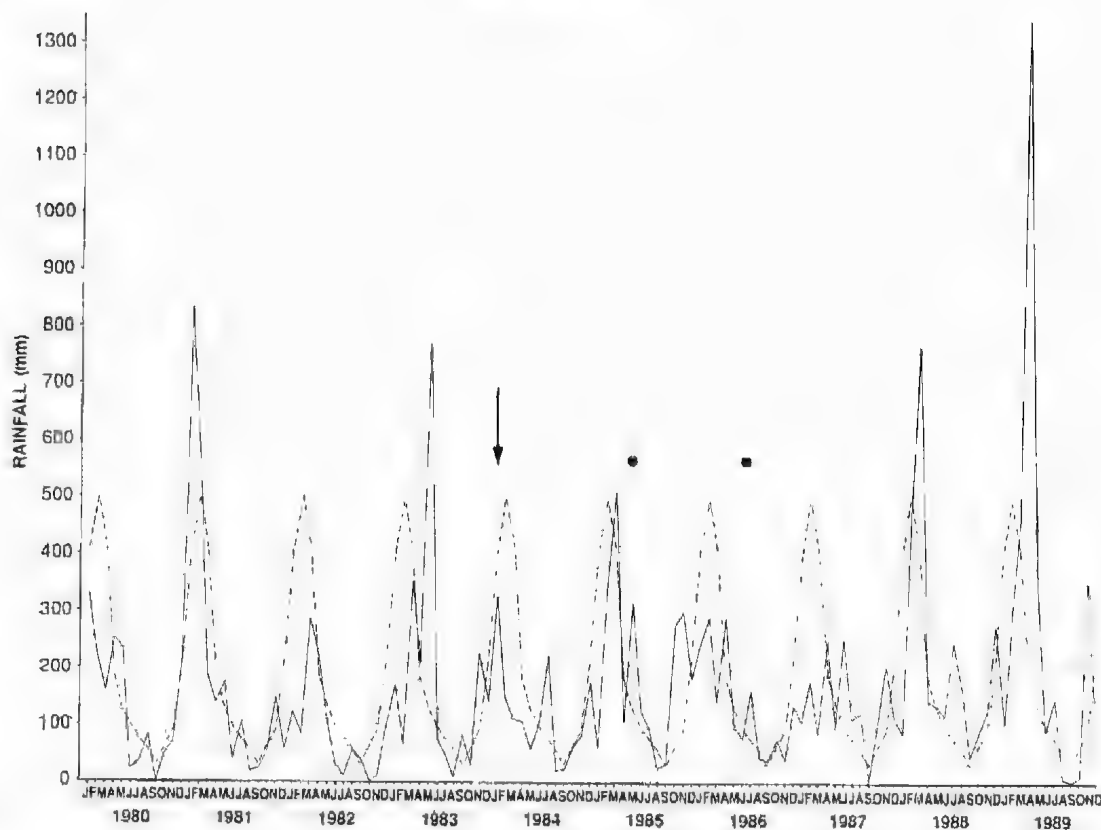


Fig. 4. Monthly rainfall data for Dalrymple Heights from 1970 to January 1990. Mean monthly records are indicated by dashed lines. An arrow indicates when *Rheobatrachus vitellinus* (January 1984) was discovered and dots indicate when *Taudactylus eungellensis* and *R. vitellinus* were last observed at monitored sites.

eungellensis. *A. brevis* was not located in March 1990 at Broken River, but dry seasonal conditions existed for the previous two months.

The disappearance of *R. vitellinus* and *T. eungellensis* throughout their ranges parallels that of *R. silus* and *T. diurnus* in southeastern Queensland as documented by Ingram (1983) and Czechura (1984) and discussed by Tyler & Davies (1985). The recent absences in the southern distribution of *Taudactylus acutirostris* in north Queensland from known habitats (unpubl. data) suggests a phenomenon similar to that which occurred for *Rheobatrachus* species and the two *Taudactylus* species. The changes have occurred over ten years, moving from south to north and affecting species in upland areas. For this reason, as indicated by Tyler & Davies (1985), legislative protection of frogs displaying large fluctuations in

populations over time is of little value — protection of habitat becomes of prime importance.

McEvoy *et al.* (1979) listed *R. silus* as common (as defined by Kirkpatrick & Lavery 1979) whilst Tyler & Davies (1985) considered the species to be abundant in 1976. Both *R. vitellinus* and *T. eungellensis* were common prior to the beginning of contraction of their ranges in January 1985.

For frog species to be common in localised areas is not unusual, especially rainforest species (Zweifel 1985; Burbidge & Jenkins 1985; McDonald *in press*), but their localised distribution does not necessarily render them endangered or vulnerable (Thomas & McDonald 1989). The status of *R. silus*, *R. vitellinus*, *T. diurnus* and *T. eungellensis* is considered at this stage to be rare. If their habitat is under stress, they must be considered to be vulnerable.

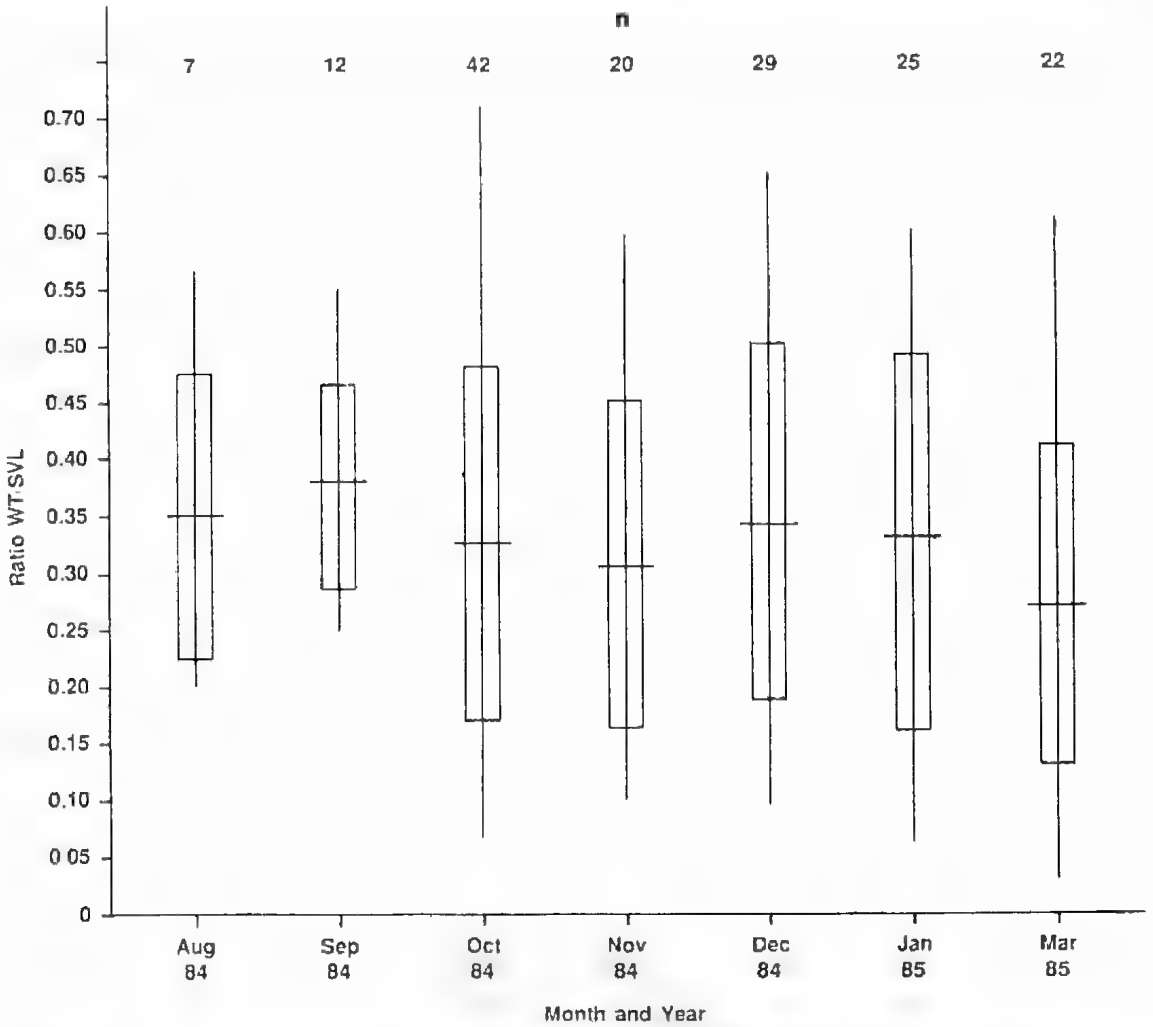


Fig. 5. Mean, range and standard deviation of ratio WT/SVL for monthly samples of *R. vitellinus* from August 1984 to March 1985.

Acknowledgments

The cause of the decline of *R. vitellinus* and *T. eungellensis* cannot be identified. The possibility remains that what has been observed is a natural population fluctuation and that residual individuals have contracted to refuges of unknown locality and nature. The amplitude of such population fluctuations is unknown, but circumstantial evidence is accumulating of similar large swings in population numbers amongst other species of Australian frogs (Tyler & Davies 1985; Winter & McDonald 1986; Tyler in press). Of great concern is the realisation of a world-wide decline in amphibian populations of unknown origin and extent (Barinaga 1990).

Dr Margaret Davies encouraged this study and provided invaluable guidance and criticism of the manuscript. Dr A. J. Butler and in particular, Drs K. F. Walker and S. C. McKillup, University of Adelaide, gave assistance with statistical advice and analysis. Staff at Eungella National Park, Kent Casey, R. Delaney, V. R. J. Hansen, M. L. Kerr, M. Pyke, D. Schulz, J. Turner, Dr J. Wade, and Dr J. W. Winter assisted in the field and in various ways. Russell Cumming drew figures 1-4 and Kelly Maurice-Jones drew figure 5. Jean McMahon typed the manuscript. All this assistance is gratefully acknowledged.

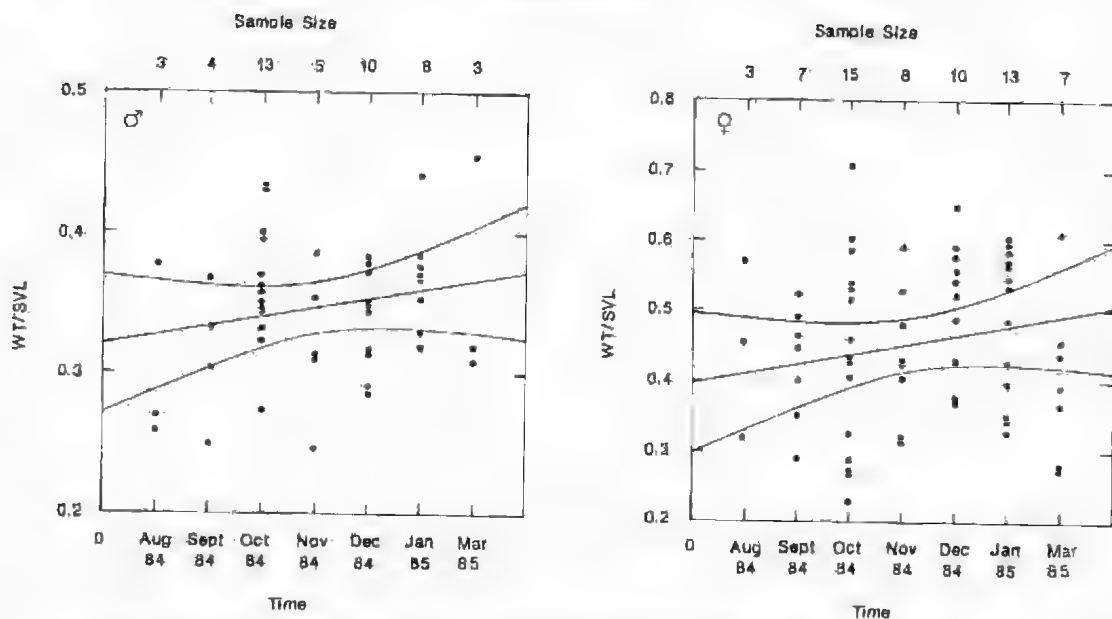


Fig. 6. Female and male weight to SVL relationships and confidence limits for samples of *R. vitellinus* from August 1984 to March 1985. Some points represent multiple samples.

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FIRST AUSTRALIAN RECORDS OF THE FAMILY PISIONIDAE (POLYCHAETA), WITH THE DESCRIPTION OF A NEW SPECIES

BY G. HARTMANN-SCHRÖDER* & S. A. PARKER†

Summary

Material of two species of *Pisione* recently collected in Spencer Gulf, South Australia, constitutes the first Australian records of the Pisionidae, a family of small interstitial polychaetes. One of the species is *P. gopalai* (Alikunhi, 1941), known previously only from India, and here redescribed with additional observations concerning its reproductive system. The second species, apparently related to *P. papillata* Yamanishi, 1976 of Japan, is described as *P. tortuosa* sp. nov.

KEY WORDS: Polychaeta, Pisionidae, *Pisione gopalai*, *Pisione tortuosa* sp. nov., Australia.

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KEY WORDS: Polychaeta, Pisionidae, *Pisone gopalai*, *Pisone tortuosa* sp. nov., Australia.

Introduction

The family Pisionidae is widely distributed in warm temperate to tropical zones, with two species (*P. longipalpa* Uschakov, 1956 and *P. remota* (Southern, 1914)) occurring in cool temperate seas. Members of the family live interstitially, preferring sandy substrates in shallow waters from the intertidal to 78 metres.

Until recently, no pisionids had been known from Australia. During a benthic survey of upper Spencer Gulf, South Australia, conducted by the S. Aust. Fisheries Dept in 1986 and 1987, a total of 342 specimens of the genus *Pisone* was collected from nine stations by Smith-McIntyre grab. Of these, 338 proved referable to *P. gopalai* (Alikunhi, 1941), known previously only from India, and four represented an undescribed species related to *P. papillata* Yamanishi, 1976 of Japan. Below, *P. gopalai* is redescribed, and the second species is described.

Material and Methods

Measurements are in millimetres, made with an eyepiece micrometer. Drawings were made with the aid of a camera lucida on a Zeiss microscope. Material is deposited in the South Australian Museum, Adelaide (SAM), Zoological Museum, Hamburg (ZMH), Australian Museum, Sydney (AM) and National Museum of Natural History, Washington DC (USNM). The terminology for the

general morphology mainly follows Southern (1914) and Yamanishi (1976); that for the reproductive structures follows Alikunhi (1941). Details of the collecting-stations are presented in Table 1.

Systematics

Family PISIONIDAE Levinsen, 1887

Genus *Pisone* Grube, 1857

Pisone gopalai (Alikunhi, 1941)

FIGS 1–12

Praegeria gopalai Alikunhi, 1941: 224, pls 10, 11, text-figs 1–27.

Pisone gopalai: Alikunhi, 1951: 24–25; Rao & Ganapati, 1968: 110.

Material examined: Station 5, SAM E2328(1); Station 6, SAM E2329(60), ZMH P19699–19700(31), AM W20109(6), USNM 127193(6) (all from a single sample of 103), SAM E2330–2341(146); Station 7, SAM E2342(1); Station 8, SAM E2343–2344(7); Station 10, SAM E2345(1); Station 15, SAM E2346, E2365–2368(94), ZMH P19697–19698(6); Station 16, SAM E2369(1); Station 25, SAM E2370–2372(7); Station 30, SAM E2373(1).

Description of new material: Largest female 57 setigers, length 8.8. Largest male 55 setigers, length 6.1. Prostomium small, surrounded by buccal segment, palps long, dorsal cirri of buccal segment elongate, very weakly annulated, ventral cirri small, globular, each with terminal papilla, two pairs of eyes on posterior lobes of brain at level of second setiger (Fig. 1). Buccal aciculae strong, tips expanded, obliquely truncate with inconspicuous dentations (Figs 2a, b).

Dorsal cirri similar in form and size, short, globular, each with terminal papilla (Figs 1, 3). Ventral cirri of setiger 1 slightly elongated; ventral cirri of succeeding setigers short, globular (Figs 1, 3).

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† South Australian Museum, North Terrace, Adelaide, S. Aust. 5000.

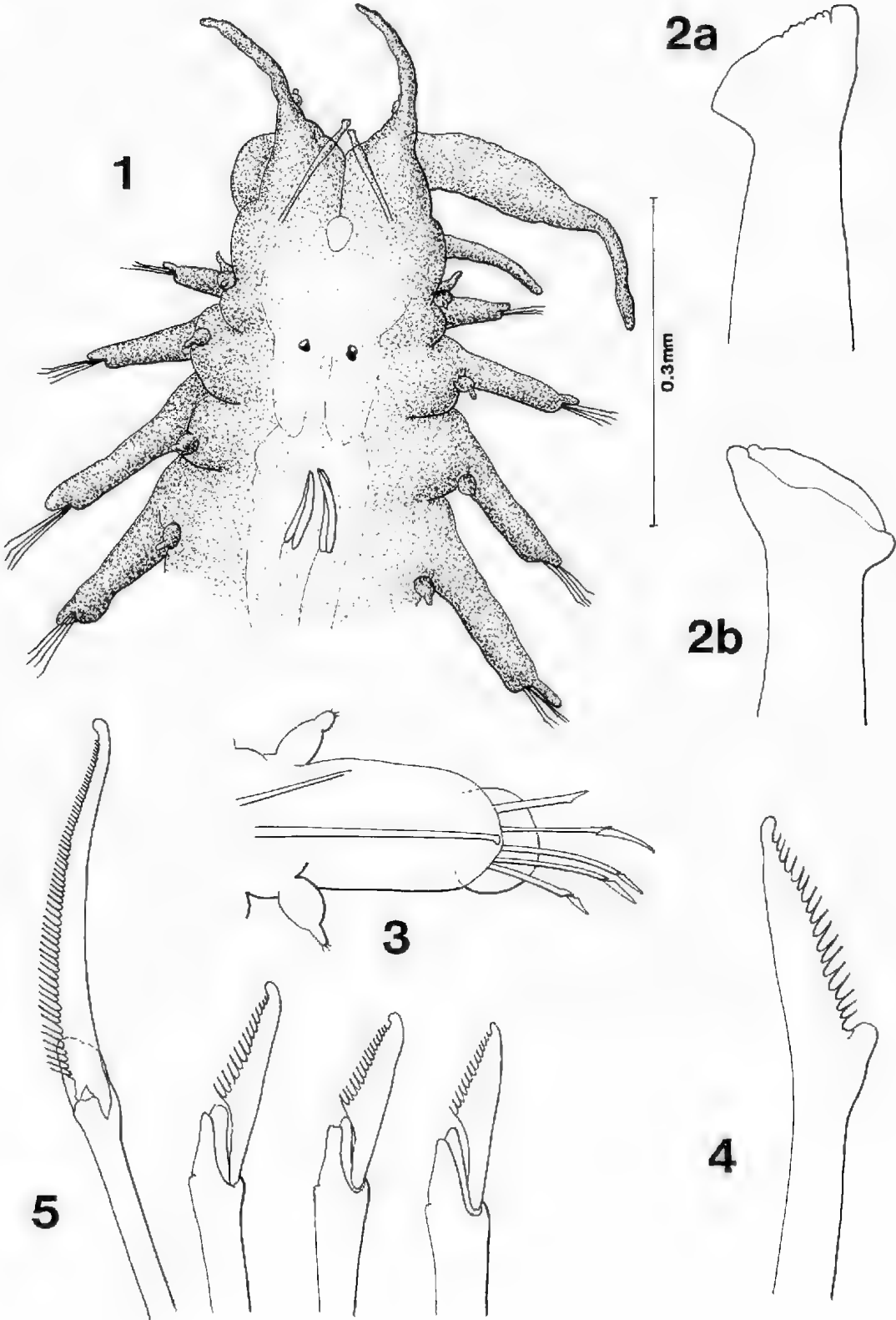


TABLE 1. Details of Stations in Spencer Gulf at which pisionids were collected.

Station	Lat. (S)	Long. (E)	Depth (m)	Sandgrain size
5	32°42'20"	137°47'26"	15	medium to coarse
6	32°45'00"	137°50'00"	16	coarse
7	32°47'18"	137°49'12"	15	coarse
8	32°47'18"	137°50'00"	11	coarse
10	32°50'00"	137°49'43"	11	medium
15	33°00'00"	137°00'00"	24	coarse
16	33°00'00"	137°49'52"	18	very coarse
25	33°02'24"	137°54'55"	12	coarse
30	33°05'00"	137°45'00"	16	medium

Parapodia elongate, truncate, each with large rounded presetal lobe and two aciculae, the upper short, the lower long and expanded distally (Fig. 3). Usually five setae per parapodium, one superior simple seta and four inferior compound fascigerous setae; simple seta stout, expanded distally with obliquely truncated, coarsely serrated tip (Fig. 4); uppermost compound seta with broad shaft and long serrated blade, inferior compound setae distally bifid with short serrated blades (Fig. 5).

Pygidium with two lateral groups of caudal glands and two long anal cirri (Fig. 6).

Reproductive System: Females. 24–57 setigers. Reproductive organs consist of 1–3 ovarian groups (Alikunhi (1941) mentioned only 1–2 groups), each extending into 5–16 consecutive segments (3–15 *sede* Alikunhi 1941), and 1–3 pairs of *receptacula seminis* corresponding to the ovarian groups and located in segment following each group. Parapodia of *receptacula seminis*-bearing segments greatly reduced, each with truncated lobes, one acicula, a dorsal cirrus and a genital papilla, last bearing common apertures of a *receptaculum seminis* and a nephridial duct (Figs 7, 8; see also Alikunhi 1941).

Of 117 females examined, 46 had one pair of *receptacula seminis*, which were located in setigers 17–45, mostly in setigers 25(5), 26(3), 27(4), 28(6) and 29(4); of these 46 specimens, 23 had 33–37 setigers. Fifty-one females had two pairs, in setigers 15–55; of these 51, 35 had 38–52 setigers. Seventeen females had three pairs, in setigers 20–53; of these 17, eight had 53–56 setigers.

Males. 21–55 setigers. Reproductive system usually consists of one pair of sperm sacs, a pair of genital funnels and a pair of copulatory organs; only one male (from SAM E2371) out of 166 males

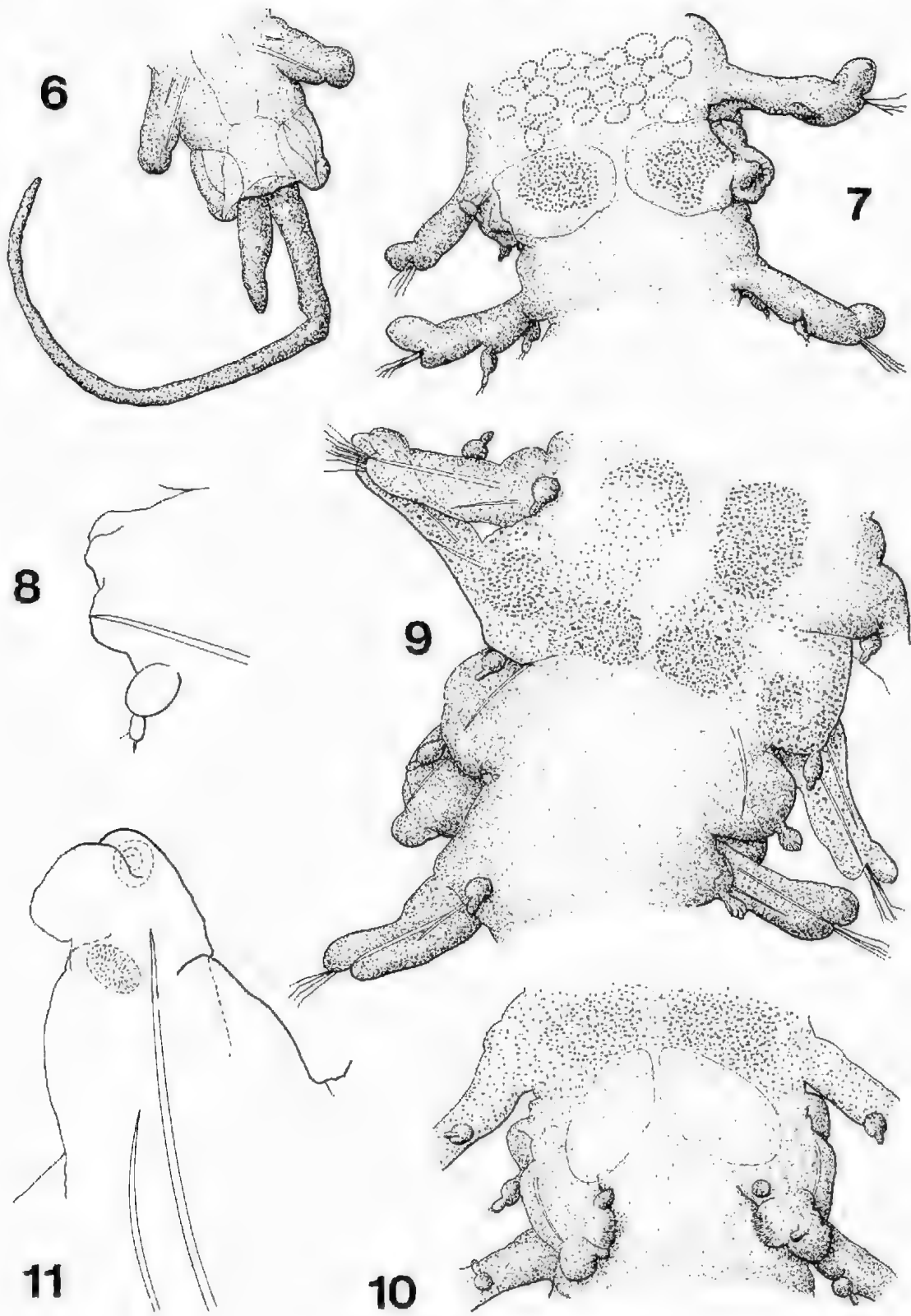
examined had two pairs of each of these structures. Parapodia of copulatory organ-bearing segment strongly modified (Figs 9–12): each parapodium ends in a papilla with stiff cuticular projections and a hook-like retractile process where efferent duct of sperm sac opens; posterior side of each parapodium also with a spinous papilla of unknown function and, more ventrally, a second process with cuticular projections (?modified ventral cirrus); dorsal cirrus, aciculae and presetal lobe of normal shape.

Copulatory organs located in setigers 15–26. Of 166 males examined, 33 had these organs in setiger 20, 30 had them in setiger 21, and 26 had them in setiger 22. In the first group, 15 specimens had 33–39 setigers, in the second group 15 had 37–40 setigers, and in the third group 13 had 36–41 setigers.

Juveniles and unsexed adults. Sixty unsexed specimens (with 9–37 setigers) were found. Most were juveniles, with fewer than 20 setigers. The other individuals might have been at a post-reproductive stage in which the reproductive organs had disintegrated and new parapodia had developed at the genital segments.

Distribution and habitat. India: Madras, Pathinettarayalam, Waltair Coast; in coarse sand of the lower intertidal; South Australia: Upper Spencer Gulf, in medium to very coarse sand of the benthos, 11–24 m.

Pisionids, being tiny and interstitial, can be easily overlooked, as demonstrated by the late discovery of this species and the next in Spencer Gulf, a relatively well-collected area. It is not unlikely, therefore, that other populations of *P. gopalai* remain to be discovered between India and Australia.



Pisone tortuosa sp. nov.
FIGS 13-17

Holotype: SAM E2325, Station 15, 24 m. in coarse sand, upper Spencer Gulf, South Australia, collected by E. Oks, S. Aust. Fisheries Dept, Feb. 1986; 94 setigers, length 16.0, width (excluding parapodia) 0.35.

Paratypes: SAM E2326(1), E2327(1), ZMH P19369(1), same data as holotype; 72-86 setigers, length 12.0-13.2.

Definition: A *Pisone* with dorsal cirri on setiger 2 elongated and evenly tapering (lacking terminal papilla); eyes at level of setiger 1; lower acicula of each parapodium amber-coloured and straight; blade of uppermost compound seta twisted and long.

Description: Prostomium diamond-shaped, very small, surrounded by buccal segment; palps large, elongate; dorsal tentacular cirri thread-like, ventral one short, globular with terminal papilla; one pair of small eyes on brain at position of first setiger (Fig. 13). Buccal aciculae strong, distally expanded, obliquely truncate with indistinct serration (Fig. 14).

Parapodia (some partly separated from body due to fixation) oblong, bearing two presetal lobes, the upper one nearly rectangular, the lower a little longer, conical; and two aciculae, superior one smaller and pale, inferior one larger and amber-coloured (Fig. 15). Dorsal cirri (except those of setiger 2) short, globular; dorsal cirri of setiger 2 elongated, tapering, with no terminal papilla, but shorter than parapodial lobe (Fig. 13). Ventral cirri of first setiger also elongated, greatly exceeding parapodial lobe; other ventral cirri globular (Figs 13, 15).

Setae comprise one superior simple seta and four compound falcigerous setae (Figs 16, 17). Simple seta stout, distally obliquely truncate, with strong dentation. Uppermost compound seta much thinner, its shaft with asymmetrical oval end, the blade long, subdistally twisted, with coarse dentation. Shafts of the three inferior compound setae distally bifid; blades short, serrated.

Etymology. The name *tortuosa*, a Latin adjective, refers to the twisted blade of the uppermost seta.

Comparison with other species

Species of *Pisone* with elongate dorsal cirri on setiger 2 are *P. africana* Day, 1963, *P. crassa* Yamanishi, 1976, *P. oerstedii* Grube, 1857 (including *P. a. pulla* Westheide, 1974) and *P. papillata* Yamanishi, 1976. In *P. africana* the second dorsal cirrus is more slender than and twice as long as the others, though of the same shape (i.e. not tapering evenly but ending in a distinct papilla); in *P. crassa* and *P. oerstedii* all the compound setae have short blades.

The four specimens from Spencer Gulf appear most similar to *P. papillata* of Japan, but differ sufficiently to merit description as a separate species. The new species is larger, 12.0-16.0 in length as opposed to 'up to 7.6 mm' in *P. papillata* (Yamanishi 1976). In addition, the distal margins of the buccal aciculae are more sharply truncated, the eyes are at the level of setiger 1 rather than setiger 2, the lower acicula of each parapodium is amber-coloured and straight rather than pale and sharply recurved at the tip, and the blade of the uppermost seta is longer and twisted.

Distribution and habitat

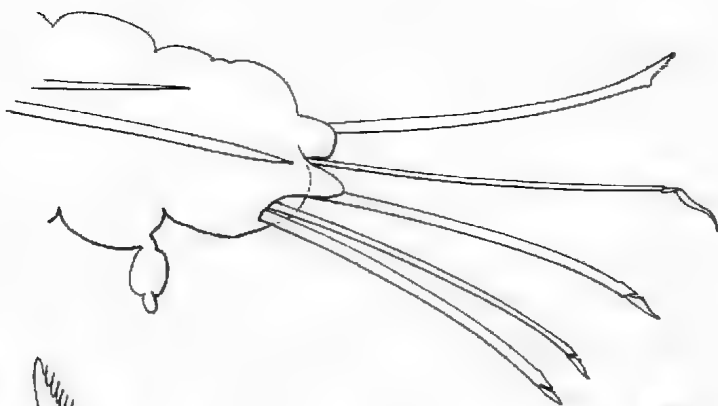
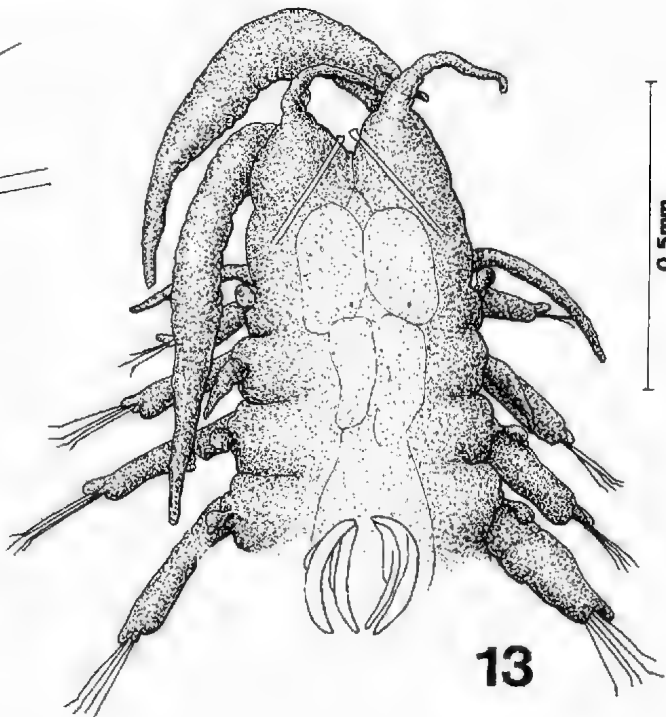
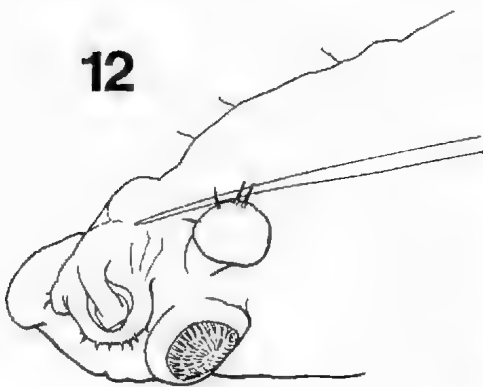
P. tortuosa is so far known only from the type-locality in upper Spencer Gulf, S.A., where it was collected at 24 m in coarse sand. The related *P. papillata* of Japan has been reported from beaches of coarse sand at Hon-jima on the island of Shikoku and Hishio on Honshu (Yamanishi 1976). localities on opposite shores of the Seto Naikai.

In Spencer Gulf, *P. tortuosa* appears less common and more localized than *P. gopalai*, having been found at only one station (four specimens), as against nine stations (338 specimens) for the latter.

Acknowledgments

We should like to thank Ms Ene-mai Oks, leader of the Spencer Gulf benthic survey, for lodging the survey's collections with the South Australian Museum, and Mr J. R. Hanley and Dr P. Hutchings for their criticism of the manuscript.

Figs 6-11. *Pisone gopalai* (Alikunli, 1941). 6, pygidium (ventral view); 7, 8, reduced parapodium of segment bearing *receptacula seminis* (dorsal view); 9, 10, segments bearing copulatory organs (dorsal and ventral views respectively); 11, modified parapodium of segment bearing copulatory organs (anterior view).



17

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Fig. 12. *Pisione gopalai* (Alikunhi, 1941). Modified parapodium of segment bearing copulatory organs (posterior view). (Figs 1–6, 9–12 from SAM E2365, figs 7, 8 from SAM E2329).

Figs 13–17. *Pisione tortuosa* sp. nov. SAM E2325: 13, anterior end (dorsal view) 14, buccal acicula; 15, parapodium (anterior view); 16, simple seta; 17, compound setae.

FIRST AUSTRALIAN RECORD OF *HESIONURA* (POLYCHAETA: PHYLLODOCIDAE), WITH THE DESCRIPTION OF A NEW SPECIES

BY G. HARTMANN-SCHRÖDER & S. A. PARKER†*

Summary

A new species of phyllodocid polychaete, *Hesionura australiensis* sp. nov., is described from Spencer Gulf, South Australia. The single specimen, collected in coarse sand at a depth of 11 metres, represents the first record of the genus *Hesionura* Hartmann-Schröder, 1958, from Australia.

KEY WORDS: Polychaeta, Phyllodocidae, *Hesionura australiensis*, new species, Australia.

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Summary

HARTMAN-SCHRÖDER, G. & PARKER, S. A. (1990) First Australian record of *Hesionura* (Polychaeta: Phyllodocidae), with the description of a new species. *Trans. R. Soc. S. Aust.* 114(4), 203-205, 30 November, 1990.

A new species of phyllodocid polychaete, *Hesionura australiensis* sp. nov., is described from Spencer Gulf, South Australia. The single specimen, collected in coarse sand at a depth of 11 metres, represents the first record of the genus *Hesionura* Hartmann-Schröder, 1958, from Australia.

KEY WORDS: Polychaeta, Phyllodocidae, *Hesionura australiensis*, new species, Australia.

Introduction

Hesionura Hartmann-Schröder, 1958 (Phyllodocidae: Eteoninae) currently contains nine described species, all of which live interstitially, most no deeper than 40 m, but one to 100 m and one to 200 m. Until recently the genus had not been known from Australia. In February 1986, during a benthic survey of upper Spencer Gulf, South Australia, the S. Aust. Fisheries Dept. collected a single specimen of *Hesionura*, which examination revealed to represent an undescribed species.

Materials and Methods

Measurements are in millimetres, made with an eyepiece micrometer. Drawings were made with the aid of a camera lucida on a Zeiss microscope. The holotype is deposited in the South Australian Museum, Adelaide (SAM).

Family PHYLLODOCIDAE Williams, 1852

Subfamily Eteoninae Bergström, 1914

Genus *Hesionura* Hartmann-Schröder, 1958

Hesionura australiensis sp. nov.

FIGS 1-5

Holotype: SAM E2324, Station 8, 32°47'18" S, 137°50' E., upper Spencer Gulf, South Australia, 11 m, in coarse sand, collected by E. Oks, S. Aust. Fisheries Dept, February, 1986.

Definition: A *Hesionura* lacking simple setae; shaft of uppermost (compound) seta trifid distally, the remainder bifid; blade of second uppermost seta 2-3 times as long as the others, serratulate, the teeth very long and fine.

Description of Holotype: Seventy-three setigers (incomplete), length 5.1, width (excluding parapodia) 0.12. Colour in alcohol brownish-green, bases of posterior parapodia containing reddish-brown pigment.

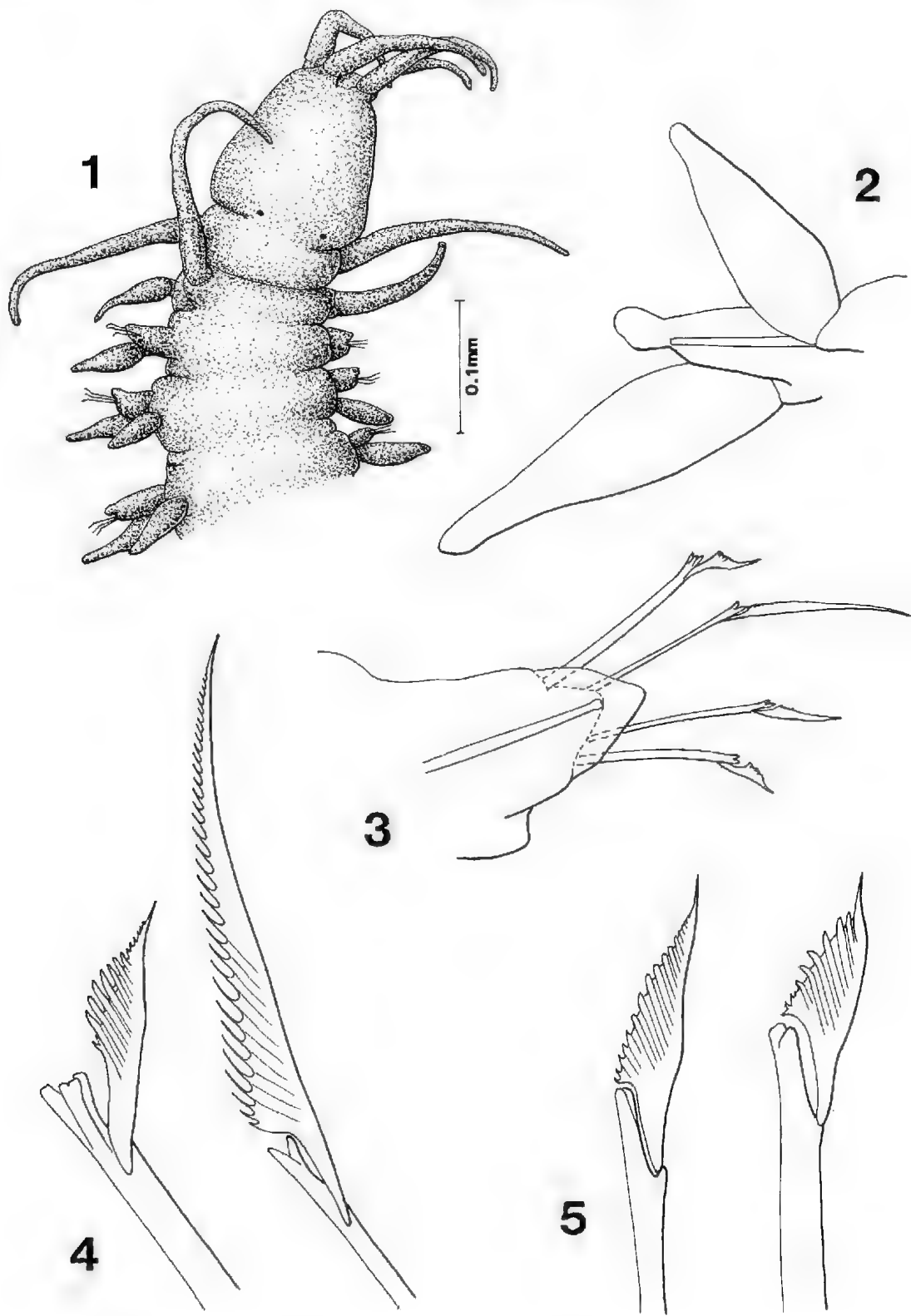
Prostomium (Fig. 1) trapezoid, length equal to greatest width, with two small red eyes near posterior margin and four elongate antennae (slightly longer than prostomium) near anterior margin. First segment not completely separated from prostomium, bearing one pair of tentacular cirri of similar shape to antennae but longer. Segment 2 with two pairs of tentacular cirri, the dorsal pair slightly longer than those of segment 1, ventral pair shorter, lanceolate. Segment 3 bearing parapodia, setae and lanceolate ventral cirri; dorsal cirri absent. Dorsal cirri of succeeding segments lanceolate to subulate, slightly exceeding parapodial lobes; ventral cirri lanceolate but much longer; parapodia conical, each with one large conical presetal lobe and one stout acicula (Fig. 2). In addition, each parapodium bears four compound setae (Fig. 3), uppermost with distally trifid shaft and short, coarsely dentate blade, next one thinner with shaft distally bifid, blade long, serratulate (Fig. 4), the two inferior setae with distally bifid shafts and short, coarsely dentate blades (Fig. 5).

Comparison with other species

Other *Hesionura* spp. lacking simple setae and with the shaft of at least the uppermost seta trifid distally are *H. coineau* (Laubier, 1962) and *H. laubieri* (Hartmann-Schröder, 1963). *H.*

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australiensis resembles *H. coineau* in having the shaft of the second uppermost seta bifid distally but differs in having the blade of the same not coarsely denticulate but serratulate, the teeth very long and fine. There are also differences in the lengths of the setal blades: in *H. c. coineau* all four are short, in *H. c. difficilis* (Banse, 1963) the uppermost and lowermost are short, the other two about twice as long, and in *H. australiensis* the uppermost and two lowermost are short, with the second uppermost 2–3 times as long. *H. australiensis* further differs from *H. coineau* in having the ventral tentacular cirri and the dorsal and ventral parapodial cirri longer. The new species resembles *H. laubieri* in having the blade of the

second uppermost seta serratulate and longer than the rest, but differs in having this blade even more elongated and its shaft distally bifid, not trifid.

Distribution and Ecology

Known only from the type-locality in northern Spencer Gulf, S.A., where the single specimen was collected in coarse sand at a depth of 11 m. Apparently much less common in the area than the equally small, interstitial polychaetes of the genus *Pisone* (Pisionidae), of which 342 specimens were obtained during the same survey (Hartmann-Schröder & Parker 1990).

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DEVELOPMENTAL BIOLOGY OF THE AUSTRALIAN HYLID FROG *NYCTIMYSTES DAYI* (GÜNTHER)

BY MARGARET DAVIES* & STEPHEN J. RICHARDS†

Summary

The Australian hylid frog *Nyctimystes dayi* (Günther) lays large unpigmented eggs that hatch no later than stage 22. Early larvae are nourished by a well-developed yolk sac and feeding commences after stage 24. Tadpoles exhibit adaptations to fast flowing streams. The mouth disc is large and sucker-like with two upper and three lower rows of labial teeth. The oral disc is hemispherical and the floor of the labrum is covered with well-developed ridges. Tadpoles can overwinter and metamorphose in the following spring/summer.

KEY WORDS: *Nyctimystes dayi*, tadpoles, life history, lotic adaptations.

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DAVIES, M. & RICHARDS, S. J. (1990) Developmental biology of the Australian hylid frog *Nyctimystes dayi* (Günther). *Trans. R. Soc. S. Aust.* 114(4), 207–211, 30 November, 1990.

The Australian hylid frog *Nyctimystes dayi* (Günther) lays large unpigmented eggs that hatch no later than stage 22. Early larvae are nourished by a well-developed yolk sac and feeding commences after stage 24. Tadpoles exhibit adaptations to fast flowing streams. The mouth disc is large and sucker-like with two upper and three lower rows of labial teeth. The oral disc is hemispherical and the floor of the labrum is covered with well-developed ridges. Tadpoles can overwinter and metamorphose in the following spring/summer.

KEY WORDS: *Nyctimystes dayi*, tadpoles, life history, lotic adaptations.

Introduction

The Australopapuan hylid frog genus *Nyctimystes* Stejneger comprises species that are associated with streams in mountainous or upland regions. The sole Australian representative, *Nyctimystes dayi* (Günther), is confined to rainforest in upland northeast Queensland (Czechura *et al.* 1987).

Parker (1936) described the tadpoles of *N. cheesmanae* (as *N. montana*) and *N. semipalmata* whilst Czechura *et al.* (1987) described a tadpole of *N. dayi*. Other than these descriptions of tadpoles little is known about the life history of *Nyctimystes* species other than that tadpoles are stream-dwelling and have sucker-like mouths (Griffiths 1963; Menzies 1974; Zweifel 1983).

In the course of a study of the community ecology of tadpoles in a rainforest stream on Mt Spec, Queensland, one of us (S.J.R.), collected and reared newly-hatched tadpoles of *N. dayi*. This series was supplemented with field-collected tadpoles at various stages. Here we describe this material and comment on the behaviour of tadpoles of *N. dayi* in the stream.

Materials and Methods

Tadpoles were collected from Birthday Creek, 7 km NW Paluma, on 16.ii.1990 and reared in aerated water in 350 ml plastic containers. Larvae fed on algae provided by algae-covered rocks.

Temperature of the room was maintained at 24–27°C. Specimens were preserved in 5% formalin.

Larvae were staged (where possible) according to Gosner (1960). Total length and body length (in mm) were taken using dial calipers measuring to 0.05 mm or an eyepiece micrometer.

Line drawings were made with the aid of a Wild M8 stereo dissecting microscope and attached camera lucida.

Field observations were made every fortnight; the creek was sampled intensively for tadpoles during the day and a 100 m stretch of creek was searched at night to record frog activity.

Results

N. dayi is a spring/summer breeder; calling was first heard on 29.ix.1989. Males called at night from rocks and low foliage along rapidly-flowing stretches of the creek. Calling had ceased by 1.iii.1990.

Amplexus is axillary (Fig. 1) and eggs are laid in a cohesive clump but with discrete egg capsules, under rocks in rapidly-flowing water (Czechura *et al.* 1987; pers. obs.). A clutch collected during February 1989 contained 107 eggs. Eggs are unpigmented and a sample of five eggs laid on 18.xii.1989 has a mean diameter of 2.5 mm (range 2.3–2.6 mm). Mean capsule diameter was 3.42 mm (range 3.3–3.5 mm). Only one capsule was evident.

The limbs develop within a membranous sac until they protrude from the sheath. Hence early limb bud stages of Gosner (1960) (i.e. stages 26–31) could not be judged without damage to larvae.

The earliest stage examined was stage 22, collected and preserved on 16.ii.1990 (Fig. 2). The

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Fig. 1. An amplexant pair of *Nyctimystes dayi* from Birthday Creek.

cornea is transparent and the auditory vesicle is apparent behind the eye. Ventrally the eye is unpigmented whilst the remainder of the eye is suffused faintly with pigment. Heavier coloration is concentrated postero- and anterolaterally along

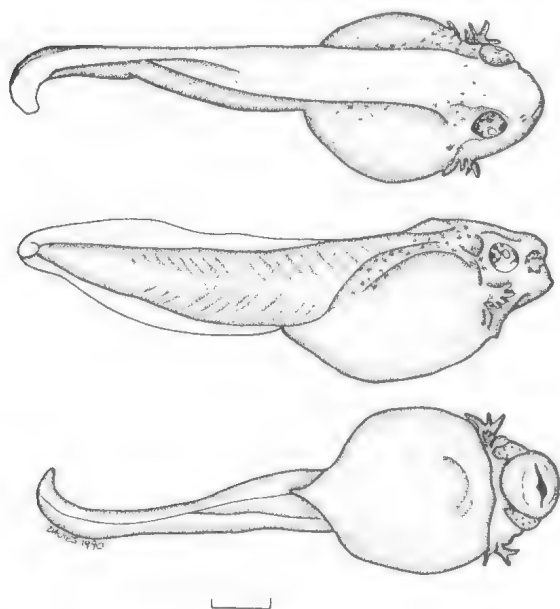


Fig. 2. Dorsal, lateral and ventral views of a newly-hatched tadpole of *Nyctimystes dayi* at stage 22 (preserved 16.ii.1990). Scale bar = 1 mm.

the dorsal surface. Two pairs of gill filaments protrude from the gill plate. The anterior gills comprise six and the posterior pair four filaments. The external nares are open and unelevated. Unpigmented adhesive organs have a flocculent appearance (Fig. 2). The transversely-oval mouth disc has formed and the mouth is open. Some ridges are apparent, precursors to the labial tooth rows and the horny beak. Labial papillae are absent. The tail is slightly curved dextrally (Fig. 2). Nutrition is supplied by a large yolk-filled body cavity. The anal tube is dextral but not open. The tail fin is transparent.

By 17.ii.1990 larvae were at stage 24. The external gills are covered by the operculum on the right hand side, but a small fringing of filaments remains exposed on the left hand side. The auditory vesicle is no longer detectable and the external nares are slightly elevated on stalks. Pigmentation of the eye is complete except for a ventral nick. The adhesive organs are undetectable. The precursor ridges of the horny beak and the labial tooth rows are clearly delineated and faint keratinization of the anterior upper tooth rows is apparent. Labial papillae are not formed. The dorsal fin extends from behind the head whilst the ventral fin extends posteriorly from the anus (Fig. 3). The tail musculature is faintly dusted with pigment granules anteriorly.

By 18.ii.1990, larvae were at stage 25. The gills are enclosed totally by the operculum and the spiracle has formed on the left hand side

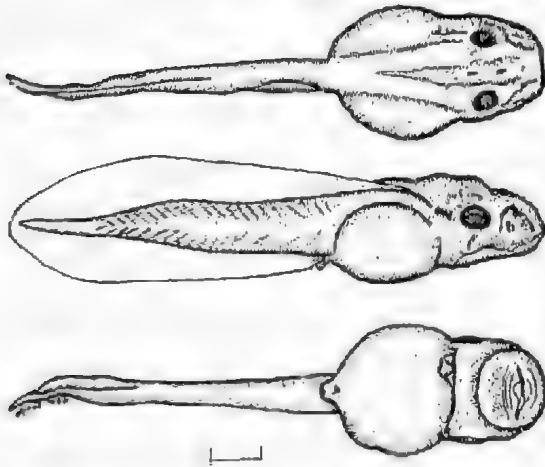


Fig. 3. Dorsal, lateral and ventral views of a tadpole of *Nyctimystes dayi* at stage 24 (preserved on 17.ii.1990). Scale bar = 1 mm.

ventrolaterally. At this stage it appears flattened and the orifice is directed posteriorly. The eye is fully pigmented. The nares are clearly elevated. Keratinization is apparent on the two upper labial tooth rows and on the horny beak. The anterior labial papillae are prominent and the ridges on the floor of the posterior lip are forming. The anal tube is open, oriented dextrally. Pigmentation is present along the dorsal musculature of the tail. The dorsal fin arises anteriorly from the junction of the body and the tail. The yolk sac is partially grooved foreshadowing the coiled gut of the feeding tadpole.

Larvae collected on 19.ii.1990 have dense body pigmentation and a light dusting of pigment in the anterior third of the tail musculature. Further tail pigmentation is confined to the dorsal extremities of the tail musculature. Two of the lower tooth rows are lightly keratinized and all labial papillae are formed. The floor ridges of the posterior lip are clearly detectable but incomplete. The spiracle remains adpressed to the ventrolateral surface of the body. The stalked nares are directed anteriorly. These larvae could not be staged because of the difficulty in locating limb buds.

Tooth rows, labial papillae and labial ridges are complete in larvae collected on 20.ii.1990. Coiling of the gut is more pronounced. The vent has moved slightly more medially and the surrounding tissue has expanded providing a sheath which protects and hides developing limb buds. The anterior attachment of the dorsal fin has moved slightly posteriorly and arises from a position slightly anteriorly from the junction of the body with the tail muscle. A faint dusting of pigment appears on the posterior extremity of the dorsal fin.

The gut is clearly coiled but remains yolk-filled in larvae sampled on 22.ii.1990. The spiracle curves posterodorsally. Although the anal tube is more medial, it still opens dextrally to the midline. The posterior lower tooth row is now complete. Pigmentation extends ventrolaterally covering portions of the yolk gut. Pigmentation is apparent on the tail fin on the medial dorsal extremities.

Dimensions of tadpoles are shown in Table 1.

A tadpole at stage 36 is illustrated in Fig. 4.

The body is widest just posterior to the eye and is broadly ovoid. The snout is evenly rounded in dorsal view and tapers to a truncated ventrally-directed upper lip. The nares are dorsolateral and elevated on tubes opening anterolaterally. The eyes are dorsolateral, moderately large and fitting snugly into the optic cup. The spiracle is sinistral, ventrolateral and not visible from above. It opens posteriorly by a narrow orifice and the diameter of the tube decreases slightly from its origin to its orifice.

The gut is coiled and the tadpole is feeding; the cloacal tube is now median. The lower limbs and developing feet protrude from a membranous sac on each side.

The tail fins are arched and rounded terminally. The dorsal fin extends for about $\frac{3}{4}$ of the tail muscle and is deepest about $\frac{1}{2}$ way along its length. The ventral fin extends from the cloacal tail piece and is deepest at its posterior $\frac{1}{3}$. The tail musculature is deep and tapers to a fine point posteriorly.

The mouth is large, transversely oval, ventral in position (Fig. 5) and occupies the area anterior to the spiracle. Papillae surround the mouth disc. The anterior papillae are more pronounced than those laterally and posteriorly, these being little more than

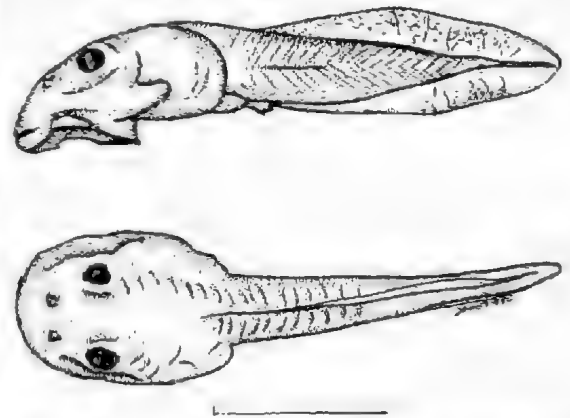


Fig. 4. Lateral and dorsal views of a tadpole of *Nyctimystes dayi* stage 36. Scale bar = 10 mm.

TABLE 1. *Body lengths of tadpoles of Nyctimystes dayi.*

Stage	Date	n	Mean body length (mm)	range	Total length
22-3	10.xi.1989	7	4.51	4.2-5.0	
25	10.xi.1989	11	7.95	7.0-8.4	
31	8.i.1990	2	14.75	14.5-15.0	
38	8.i.1990	4	15.05	14.5-15.8	
39	1.ii.1990	2	16.05	15.6-16.5	
42	1.ii.1990	1	15.6		
22	16.ii.1990	2	4.08		9.28
24	17.ii.1990	1	4.2		10.9
25	18.ii.1990	1	4.6		11.5
indet.	19.ii.1990	1	4.8		11.7
indet.	20.ii.1990	1	4.8		12.2
indet.	21.ii.1990	1	5.1		12.8
indet.	19.i.1990	1	6.2		15.0
indet.	19.i.1990	1	7.5		16.7
indet.	19.i.1990	1	7.9		19.2
indet.	19.i.1990	1	9.4		19.9
indet.	19.i.1990	1	8.7		20.9
indet.	19.i.1990	1	8.6		21.0
indet.	19.i.1990	1	8.7		21.3
indet.	19.i.1990	1	10.7		25.9
36	19.i.1990	1	12.5		32.8
37	19.i.1990	1	13.6		35.0
41	19.i.1990	1	14.3		35.6

serrations in some areas. The lateral edges of the mouth are directed dorsally (Fig. 4) (a laterodorsally curved lip). The posterior surface of the mouth disc (behind the tooth rows) is inclined posteroventrally and is ridged medially across its width. Some ridges are complete, others comprise two or three elevations. There are two upper and three lower complete labial tooth rows comprising short, very closely-applied, keratinized teeth. The horny beak is of moderate proportions.

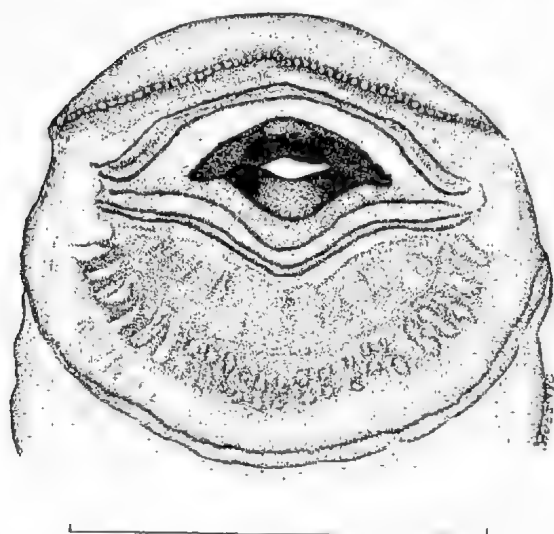


Fig. 5. Mouth disc of a tadpole of *Nyctimystes dayi* at stage 36. Scale bar = 5 mm.

The flesh of the mouth disc is translucent and unpigmented. The body is pigmented and pigmentation extends lightly along the dorsal and medial portions of the tail musculature. The remainder of the tail musculature is dusted with pigment granules. Small areas of the fins are lightly pigmented and sparse chromatophores are located elsewhere on the fins.

Tadpoles from eggs laid in early summer complete development in 3-4 months. Those eggs laid in late summer may overwinter and metamorphose the following summer (Trenerry 1988[†]; pers. obs.).

At metamorphosis one froglet measured 15.5 mm S-V and was light grey with dark flecks.

Stage 22-23 tadpoles remain attached to the egg mass under rocks in riffles and do not disperse until at least stage 24. At this stage the oral disc is well developed.

Stage 25 larvae (but with yolk still visible in the gut) were occasionally found aggregated in large numbers under single rocks. Aggregation behaviour also was observed in the laboratory: tadpoles from a single clutch aggregated in a clump which immediately reformed after disturbance. This behaviour persisted until the gut was fully formed.

In life, early stage tadpoles (stages 22-23) are bright yellow; later stages become pigmented with

[†] Trenerry, M.P. (1988) The ecology of tadpoles in a tropical rainforest stream. Honours thesis, Dept of Zoology, James Cook University of North Queensland. Unpubl.

pale brown. These tadpoles have distinct light patches on the tail.

During the day, tadpoles graze on algal-covered rocks in the fastest torrents of the stream. When disturbed they release their grip on the rocks and are swept a short distance downstream where they shelter under rocks or in rock crevices. Tadpoles are very strong swimmers, but their ability to remain in riffles even during the strongest floods (as evidenced by sampling following cyclones) probably is aided by sheltering under rocks.

Discussion

Tadpoles of *N. dayi* are adapted to fast-flowing mountain streams. The ventral, suctorial mouth-discs, the narrow tail fins and the ventrolateral spiracular opening are characteristic of species occurring in torrent environments (Duellman & Trueb 1986). The development of the larval gut parallels that described in the sympatric *Litoria eucnemis* by Davies (1989), but *N. dayi* exhibits more extreme adaptations to the lotic life style.

The tooth row pattern is similar to other hylids (Martin & Watson 1971), although the undivided

nature of all the tooth rows is unusual amongst Australian hylids, being shared by *L. lesueuri* which also shows lotic adaptations (Martin & Watson 1971).

The median vent found in later-stage tadpoles is shared by congeners but is unusual amongst hylids (Martin & Watson 1971). The covering by a membranous sac of the developing hind limb buds is presumably an adaptation to protect these structures. This feature has been observed in the limnodynastine *Mixophyes* spp. (Watson & Martin 1973; Davies in press) and *L. nannotis* (pers. obs.). Larvae of these species are lotic and found in fast-flowing streams.

Acknowledgments

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THE NATURE AND INCIDENCE OF POST-AXIAL, SKELETAL ABNORMALITIES IN THE FROG *NEOBATRACHUS CENTRALIS* PARKER AT OLYMPIC DAM, SOUTH AUSTRALIA

by JOHN L. READ* & MICHAEL J. TYLER†

Summary

READ, J. L. & TYLER, M. J. (1990) The nature and incidence of post-axial, skeletal abnormalities in the frog *Neobatrachus centralis* Parker at Olympic Dam, South Australia. *Trans. R. Soc. S. Aust.* 114(4), 213-217. 30 November, 1990.

Samples of 315 specimens of the frog *Neobatrachus centralis* from four sites at Olympic Dam, South Australia, included 12 specimens exhibiting skeletal abnormalities of the limbs. Examination revealed a predominance amongst the abnormal specimens of partial or complete ectrodactyly, most commonly involving terminal components of the fourth toe. The overall incidence of abnormalities is comparable to those occurring at undisturbed sites in other countries.

Radionuclide levels in tadpoles from the sampled sites were very low or not detectable, and were not associated with the incidence or nature of the abnormalities there.

KEY WORDS: Skeleton, abnormalities, *Neobatrachus centralis*, radionuclides.

Introduction

Olympic Dam Operations (O.D.O.) manages a large copper-gold-uranium-silver mine at Olympic Dam, approximately 500 km north of Adelaide. Mining commenced in 1984 and the metallurgical plant there started production in August 1988.

Airborne, aquatic and biotic environments are monitored stringently for both conventional (e.g. SO_2 , SO_3 and total particulates), and radioactive emissions by Olympic Dam Operations, in accordance with the South Australian Government approved Environmental Management Program (Roxby Management Services 1986), and the Waste Management Program, Olympic Dam Project (O.D.P. 1987). The plant and animal communities in all habitats in the Olympic Dam region are monitored regularly to determine the possible effects, if any, of the mining and processing operations on species diversity, abundance and condition. There have been no measurable effects on the environment, outside the immediate vicinity of the metallurgical plant, that can be attributed to the mining or processing operations (O.D.P. unpubl.).

In addition to the general monitoring program, more detailed studies are conducted on certain indicator organisms, such as frogs, to enhance the sensitivity of the monitoring program. Frogs are very sensitive to radiation (Emery & McShane 1980) and have proved to be useful indicators of radioactive emissions (Nishimura 1967; Tyler 1989)

and trace elements (Browne & Dumont 1979). Frogs are also the most common vertebrate animals associated with claypans: regions of natural heavy metal and radionuclide accumulation. A photograph of one of the claypans at Roxby is presented by Tyler (1989, plate 3).

Following rains in the semi-arid Olympic Dam region, the frog *Neobatrachus centralis* is exceptionally common adjacent to claypans and flooded swales (O.D.O. unpubl.). The ease of capture and identification of physical abnormalities in live specimens makes it an ideal subject as a potential indicator of environmental emissions at Olympic Dam.

Here we document an initial survey of frog deformity levels at control sites where there are negligible emission levels, and at sites in close proximity to the metallurgical plant where emission levels, while remaining very low, are detectable (O.D.O. 1989¹).

Materials and Methods

On 12.iv.1989, approximately 80 tadpoles were collected from two water bodies within 1 km of the Olympic Dam mine and metallurgical plant (Claypan, ENW5), and from a pond 16 km south of the mine (EV 308) (Fig. 1). The EV 308 site is near a continuous radionuclide and airborne emission monitoring site. It has not detected any emissions from the mine, and hence is a valid control site.

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¹ Olympic Dam Operations (1989) Environmental Radiation Monitoring Annual Report. (Report to the S.A. Govt) Unpubl.

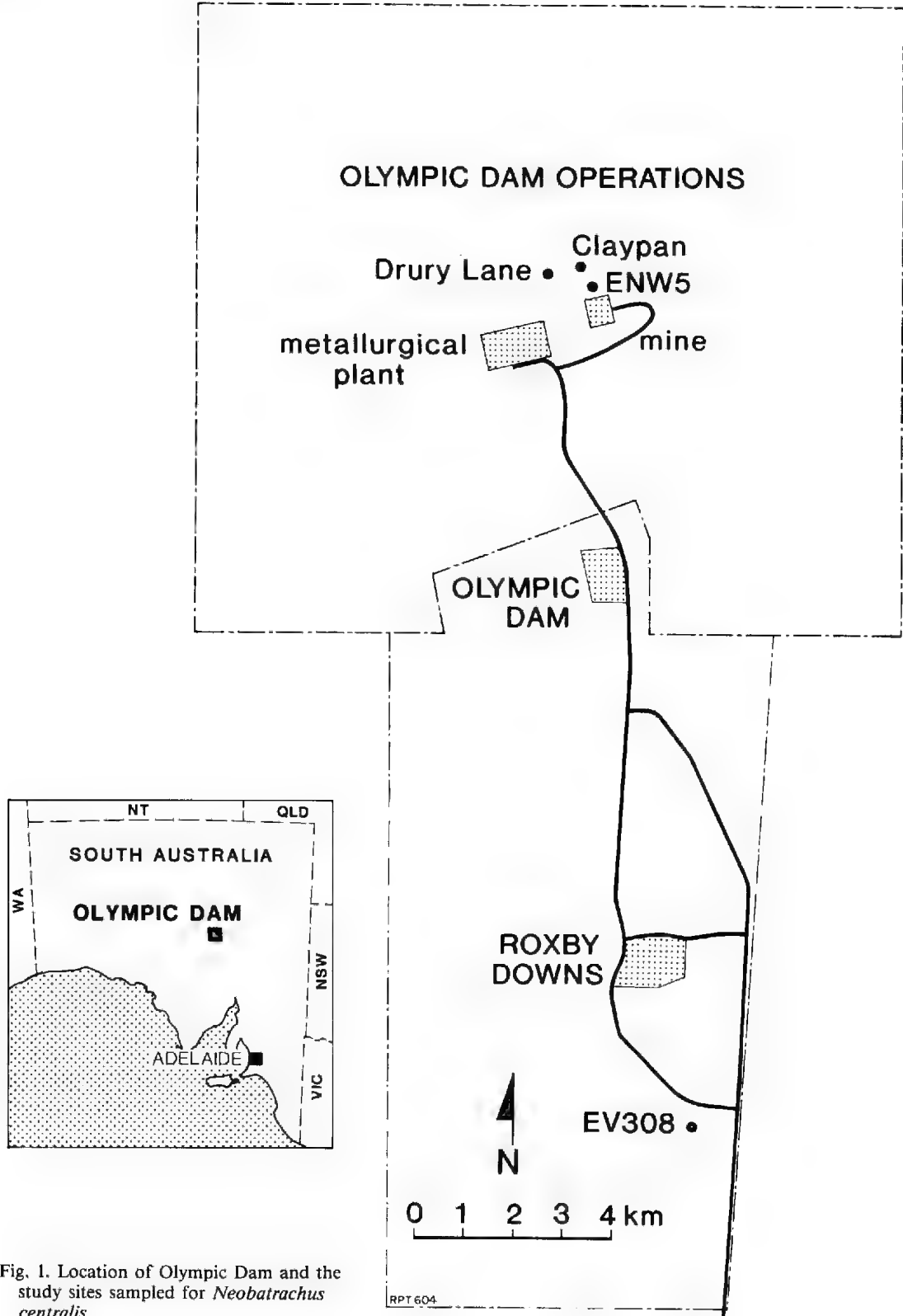


Fig. 1. Location of Olympic Dam and the study sites sampled for *Neobatrachus centralis*.

A sample of the tadpoles from each site (approximately three weeks old at the time of capture) were weighed and measured, and their stage of development recorded (Table 1). The tadpoles were housed in clean glass aquaria in the Environmental Laboratory at the Olympic Dam Village. Mud and water from each study site was used in the respective aquaria and, because individuals were in the non-feeding stage near metamorphic climax, food was not provided. Care was taken to ensure that the tadpoles were not subjected to any contaminants in the laboratory. In addition, 70 recently metamorphosed frogs were collected from a roadside near the mine (Drury Lane Site).

Following metamorphosis (i.e. complete resorption of the tail; Gosner (1960), stage 46) external features were examined under a Wild M5 dissecting microscope. Individuals with physical abnormalities were killed by exposure to 3% chloral hydrate solution and cleared and stained with Alizarin Red following the method of Davis & Gore (1947).

Five to ten metamorphosing frogs were sampled subsequently from the three water bodies and placed in a clean beaker with distilled water for several days to permit total evacuation of the gut. Earlier trials showed that freshly caught frogs and tadpoles contained considerable quantities of soil and waste matter which contributed significantly to levels of heavy metals and other contaminants. The evacuated frogs were sacrificed in ether and dissolved in Nitric and Perchloric acids. Levels of radionuclides (Po210, Pb210, Ra226, U238, Th230) were determined in the low level radiation counting laboratory of the O.D.O. Environmental Department.

Results

The average sizes, wet weights and developmental stages of the tadpoles captured at the three sites are presented in Table 1. Considerable variation existed

between the sites: specimens from EV 308 (control) and Claypan being considerably heavier than those from ENW5, while individuals from EV 308 and ENW5 were more advanced than specimens from Claypan.

Of the 315 frogs examined, 12 individuals exhibited externally detectable abnormalities of the hindlegs. Further skeletal abnormalities of other elements were revealed in one when the series had been cleared and stained. The nature of the abnormalities observed in the series is documented in Table 2.

Radionuclide levels in the frogs from all three sites are presented in Table 3. These results indicate that radionuclide levels at the control site, EV 308, were slightly higher than at the sites close to the metallurgical plant.

Discussion

In all populations of vertebrate animals there are skeletal abnormalities, whose nature and incidence may be influenced by exposure to a variety of environmental insults. It is therefore important to establish baseline data when any environmental perturbation may have an impact upon that incidence.

Tyler (1989) reported that skeletal abnormalities in the limbs of vertebrates were up to 3%: this being the naturally occurring abnormalities in any population. In the case of frogs, from supposedly undisturbed localities in six countries, limb abnormalities ranged from 0 to 3.09%, but with only one sample exceeding 2%. The impact of trauma, being physical injury within the life of individuals, needs to be distinguished. It was recorded in 2742 specimens (representing seven species) from Jabiru, N.T., and was estimated at 0.19 to 0.99%.

The incidence of abnormalities at Roxby Downs (Table 2) is equivalent to 3.8%, which is close to that reported by Tyler (1989) from undisturbed areas elsewhere. There is no evidence of trauma in our

TABLE 1. Mean wet weights and measurements of tadpoles from three study sites at Olympic Dam

Site	Sample size	Weight (g)	Body length (mm)	Tail length (mm)	% with hind legs stage 24 (Gosner 1960)	% that had reached stage 42 (Gosner 1960)
EV 308	16	2.6	25	29	100	60
ENW5	28	1.1	20	21	68	32
CLAYPAN	22	2.2	24	27	77	0

TABLE 2. *Details of abnormalities detected.*

Site	Sample Size	Incidence	Frog Ref.	Abnormality
ENW5	85	3.5%	1.	Brachymely of R leg. Urostyle inclined dextrally. Sacrum misshapen. Ectrodactyly of F3 of R hand.
			2.	Bilateral ectrodactyly T4 mainly involving antepenultimate phalanx which is discoid.
			3.	Ectrodactyly T4 R leg; one phalanx lost.
CLAYPAN	73	1.4%	1.	L foot with abnormal metatarsals 3-5: 3 abbreviated; 4 with distal excrescences; 5 with proximal and distal excrescences.
EV 308	89	9.0%	1.	R foot with ectrodactyly of T4; proximal phalanx dilated distally.
			2.	L foot lacking digits 1-2.
			3.	Brachymely of R leg involving tibia, tarsi and all digital elements.
			4.	L foot with ectrodactyly of T4: lacking 3 terminal phalanges.
			5.	L foot with ectrodactyly of T4: 2 terminal phalanges missing, antepenultimate phalanx broadened.
			6.	R foot as for 5.
			7.	L foot as for 5.
			8.	Brachydactyly of all digits of R foot; T4 only one lacking terminal phalanges.
DRURY LANE	71	0%		

TABLE 3. *Levels of radionuclides detected in metamorphosing frogs from three study sites at Olympic Dam.*

Site	Weight sampled (g)	Uranium — 238 Bq/g	Thorium — 230 Bq/g	Radium — 226 Spec Act/Bq/g	Lead — 210 Spec Act/Bq/g	Polonium — 210 Bq/g
EV 308 (control)	6.46	0.0003 +/- 0.0002	0.004 +/- 0.002	.004 +/- .002	0.011 +/- 0.006	0.053 +/- 0.006
ENW5	11.65	N.D.	N.D.	.0007 +/- .0005	0.001 +/- 0.002	0.005 +/- 0.001
CLAYPAN = ENW5 (n)	11.23	N.D.	0.001 +/- 0.0004	.0019 +/- .0009	0.006 +/- 0.004	0.132 +/- 0.011
STANDARD	—					

N.D. = Not detected
 Deviation quoted is counting statistic

samples. Low abnormality rates at sites near the mine (0 to 3.5%) contrasted with higher rates from the control site (EV 308). Conspicuous amongst the abnormalities at Roxby Downs is the predominance of partial ectrodactyly, principally of the fourth toe. It is expressed more commonly by a unilateral reduction of the normal phalangial formula. Although ectrodactyly is one of the most common forms of skeletal abnormality in Australian frogs, the similarity of the digital target in this sample is noteworthy. Breeding experiments will be required to determine if this is a common mutant.

Variations in weight and size of the tadpoles from the different sites is probably related to food availability, water temperature and turbidity and genetic factors rather than pollutant levels in their ponds. Richards (1962) and Sokol (1984) have also demonstrated that growth suppressing substances released by tadpoles results in slower growth rates in densely crowded tadpoles compared with tadpoles reared at lower densities.

Slightly higher levels of radionuclides at the control site compared with the mine sites is not an

effect of the project but a natural phenomenon. Due to the natural variation in soil radionuclide concentrations (United Nations Scientific Committee on the Effects of Ionising Radiation 1977) geographical variation in radionuclide levels can be expected.

Acknowledgments

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Comparative abnormality data cited from Jabiru were assembled by M. J. Tyler in collaboration with Graeme Crook, Margaret Davies and Graeme Watson, and funded by the Office of the Supervising Scientist, Alligator Rivers Region. Technical assistance was provided by Leanne Seller and the manuscript typed by Lorna Lucas.

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***PSEUDOCRISTIANELLA* (CESTODA: TRYPANORHYNCHA),
A NEW GENUS FOR *TENTACULARIA MINUTA* (VAN BENEDEN, 1849)
SENSU SOUTHWELL, 1929 AND ITS RELATIONSHIPS WITH THE
FAMILY EUTETRARHYNCHIDAE**

BY R. A. CAMPBELL & I. BEVERIDGE†*

Summary

Pseudochristianella southwelli gen. et sp. nov. is created for *Tentacularia minuta* Van Beneden, 1849 of Southwell, 1929 from an unknown species of *Carcharhinus* and *Rhynchobatus halavi* taken at Negapatam, India. *Pseudochristianella* is a eutetrarhynchid with two bothridia, elongated bulbs and a heteroacanthous, heteromorphous armature that combines features of *Parachristianella*, *Trimacracanthus* and *Prochristianella*. The new genus is distinctive in combining the metabasal armature of *Parachristianella* and *Trimacracanthus* (hooks 1(l') of each row largest, the remaining hooks decreasing in size), and a prominent basal swelling on each tentacle as in *Prochristianella* and *Trimacracanthus*. *Parachristianella* differs in lacking a tentacular basal swelling and *Trimacrancanthus* is distinguished by the three large hooks of the basal armature. *Prochristianella* has a basal swelling but the metabasal hooks increase in size at the middle of each row.

KEY WORDS; Cestoda, Trypanorhyncha, *Pseudochristianella*, new species, new genus.

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Summary

CAMPBELL, R. A. & BEVERIDGE, I. (1990) *Pseudochristianella* (Cestoda: Trypanorhyncha), a new genus for *Tentacularia minuta* (Van Beneden, 1849) sensu Southwell, 1929 and its relationships with the family Eutetrarhynchidae. *Trans. R. Soc. S. Aust.* 114(4), 219-222, 30 November, 1990.

Pseudochristianella southwelli gen. et sp. nov. is created for *Tentacularia minuta* Van Beneden, 1849 of Southwell, 1929 from an unknown species of *Carcharhinus* and *Rhynchobatus halavi* taken at Negapatam, India. *Pseudochristianella* is a eutetrarhynchid with two bothridia, elongated bulbs and a heteroacanthous, heteromorphous armature that combines features of *Parachristianella*, *Trimacracanthus* and *Prochristianella*. The new genus is distinctive in combining the metabasal armature of *Parachristianella* and *Trimacracanthus* (hooks 1(1') of each row largest, the remaining hooks decreasing in size), and a prominent basal swelling on each tentacle as in *Prochristianella* and *Trimacracanthus*. *Parachristianella* differs in lacking a tentacular basal swelling and *Trimacracanthus* is distinguished by the three large hooks of the basal armature. *Prochristianella* has a basal swelling but the metabasal hooks increase in size at the middle of each row.

KEY WORDS: Cestoda, Trypanorhyncha, *Pseudochristianella*, new species, new genus.

Introduction

One of the species of trypanorhynchs from elasmobranchs from the Indian Ocean which Southwell (1929) allocated to the genus *Tentacularia* was *T. minuta* (Van Beneden, 1849). Southwell's hosts were an unidentified species of *Carcharhinus* and *Rhynchobatus halavi* (Försskal, 1775) both taken at Negapatam, India. Beneden's (1849) original description of this species was from an angelshark, *Squatina squatina* (L.), in Belgian waters but the description is so meagre that Southwell's specimens cannot be considered conspecific with any degree of confidence. Guiart (1931) placed *T. minuta* in his new genus *Christianella*, for which a more detailed description was given by Joyeux & Baer (1936). Dollfus (1942) initially accepted this description, but later (1946) found that the description of *Christianella* was vague and created the related genera *Prochristianella* and *Parachristianella* realizing that either might be a synonym of *Christianella* when the latter genus was properly described. Beveridge & Campbell (1987) have discussed the problems associated with *Christianella* and also consider that genus unrecognizable. Dollfus (1942) pointed out several errors in Southwell's (1929) account of *Tentacularia minuta* including his report of this species from an Australian ray. In this paper all of Southwell's specimens labelled *T. minuta* have been

re-examined and constitute an undescribed species having characters fitting neither *Prochristianella* nor *Parachristianella* according to the most recent definitions of these genera (Schmidt 1986).

Materials and Methods

Four specimens identified by Southwell as *T. minuta* (Van Beneden, 1849) from *Carcharhinus* sp., Negapatam, India (British Museum, Natural History, London) (1977.11.4.30-31) and two specimens from *Rhynchobatus halavi* from the same locality (BMNH 1977.11.4.27-28) were examined. All figures are drawn from the specimens from *Carcharhinus*. Measurements are in mm unless otherwise indicated.

***Pseudochristianella* gen. nov.**

Diagnosis: Eutetrarhynchidae. Small worms with two bothridia and elongate bulbs. Prebulbar organs present. Pars postbulbosa and velum absent. Metabasal armature heteroacanthous, heteromorphous, typical. Metabasal hooks arranged in alternating half-spiral rows. Hooks 1(1') large, separated by prominent space, remaining hooks of each row decreasing in size. Basal swelling on tentacle. Distinctive basal armature present, restricted to external face of tentacle. Segments acraspedote; testes tandem, in two rows; internal and external seminal vesicles absent. Adults parasitic in selachians.

Type and only species: *P. southwelli* sp. nov.

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Pseudochristianella southwelli gen. et sp. nov.
FIGS 1-9

Tentacularea minuta: Southwell 1929 pp. 228-230, fig. 13.

Types: Holotype from *Carcharhinus* sp., Negapatam, India, 7.ix.1926, collector ? J. Pearson in BMNH no 1977.11.4.30-31; three paratypes on single slide, same data and collection number.

Material examined: From *Carcharhinus* sp.: types. From *Rhynchobatus halavi*, two specimens, Negapatam, India, (BMNH 1977.11.4.27-28) (slide also contains *Phyllobothrium* sp.)

Etymology: The species is named after T. Southwell.

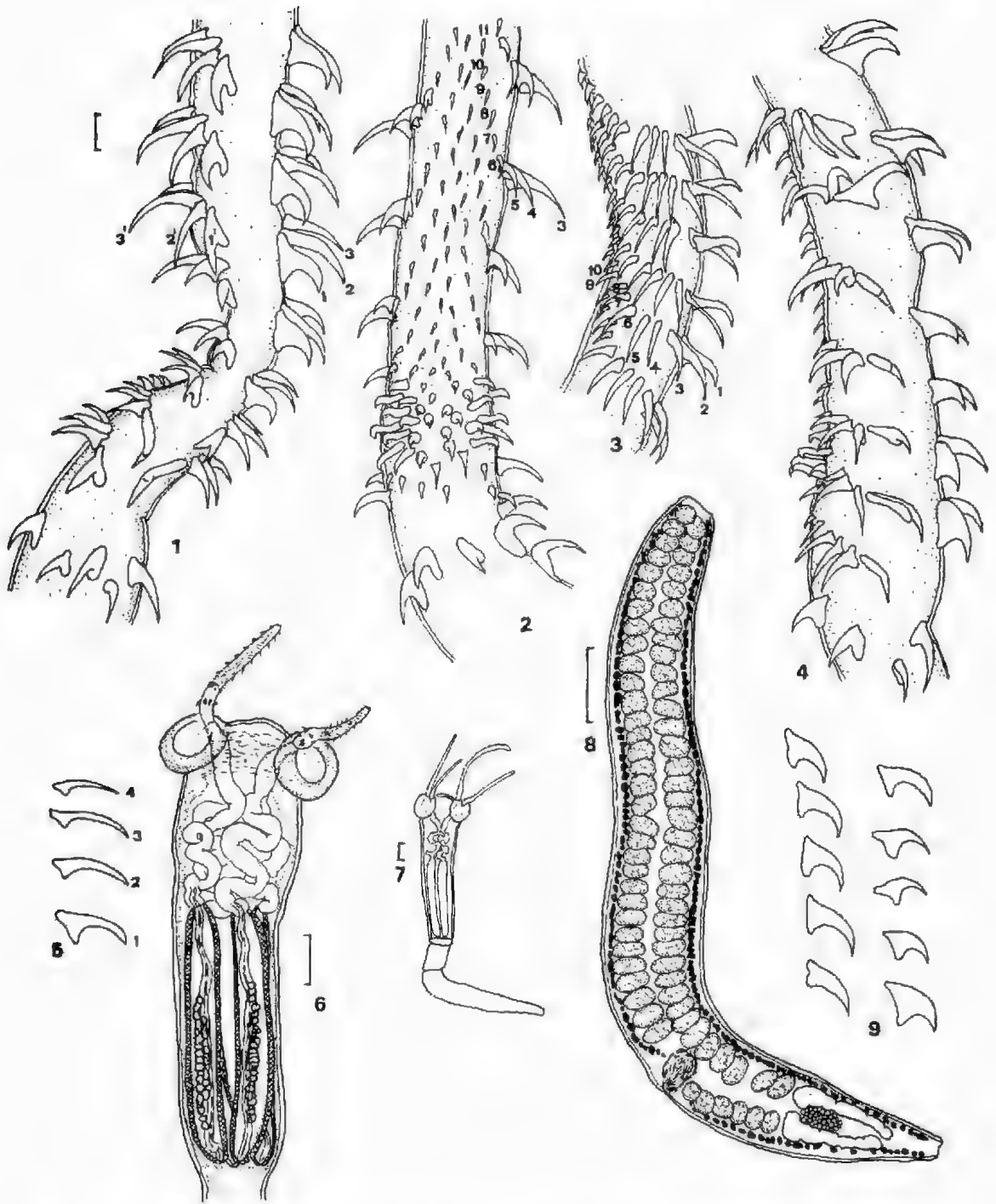
Description: Small cestodes, total length up to 4.0, with up to six proglottids. Scolex 0.92-1.00 (0.97, $n=3$) long, maximum width 0.21-0.26 (0.24, $n=4$). Two rounded bothridia, 0.12-0.18 (0.15, $n=4$); pars vaginalis 0.37-0.51 (0.42, $n=3$), tentacle sheaths sinuous; prebulbar organs present; bulbs long and slender, 0.45-0.58 (0.51, $n=4$) by 0.06-0.07 (0.07, $n=4$); retractor muscle originates at base of bulb, surrounded by clusters of gland cells within bulb; pars postbulbosa and velum absent. Tentacles possess prominent basal swelling 0.025-0.030 (0.027, $n=4$) in diameter; diameter in metabasal region 0.010-0.015 (0.013, $n=2$). Base of tentacle encircled by two rows of large, strongly recurved hooks, 0.014-0.022 (0.018, $n=5$) long, base length 0.010-0.012 (0.011, $n=5$); remainder of armature heteroacanthous typical, composed of ascending half-spiral rows of 11 hooks each; rows terminate on external face to form inverted V's. Distinctive basal armature restricted to external face of tentacle, composed of four to five ascending rows of hooks. Viewed from the external face, hooks of first row spiniform; hooks of succeeding three to four rows bill-hook shaped, small and stout, points strongly recurved, hook length 0.009-0.013 (0.011, $n=5$). Hooks 1(1') on internal surface separated by distinct space; hooks initially uncinate in basal region, 0.014-0.018 long, base length 0.012-0.013. Hooks 1(1') in metabasal region becoming falcate with diminishing base lengths, 0.014-0.020 (0.017, $n=5$) long, base length 0.007-0.011 (0.010, $n=5$). Hooks 2(2') falcate, stout at base of tentacle, becoming slender anteriorly, 0.017-0.022 (0.019, $n=5$) long, base 0.005-0.006 (0.005, $n=5$). Hooks 3(3') falcate 0.020-0.022 (0.021, $n=5$) long, base 0.005-0.006 (0.006, $n=5$). Hooks 4(4') slender, falcate, 0.016-0.018 (0.017, $n=5$) long, base 0.004-0.005 (0.005, $n=5$). Hooks 5(5') falcate, smaller, 0.010-0.014 (0.012, $n=5$) long, base 0.003-0.004 (0.003, $n=5$). Hooks 6(6') spiniform, 0.008-0.012 (0.010, $n=5$) long. Hooks 7(7') to 11(11') in metabasal region distinctly smaller than hooks 6(6'), hook lengths 0.004-0.006 (0.005, $n=3$); diminishing hook sizes more subtle in mid-region of tentacle.

Mature segment 2.14 by 0.26, acraspedote. Genital pore opens in posterior one-third of margin, approximately 78% of segment length from anterior end. Cirrus sac ovoid, internal details not clearly visible, seminal vesicles absent. Testes number approximately 80, arranged in two longitudinal rows, distributed as 6 postporal, 32 preporal and 42 antiporal. Ovary bilobed in dorsoventral view, lobes 0.14 by 0.04. Mehlis' gland 0.06 in diameter. Vitellaria arranged in single layer of follicles encircling internal organs. Uterus tubular, median, linear, occupying all available space in gravid segment.

Discussion

Tentacularea minuta of Southwell (1929) possesses a combination of characters not found in other eutetrarhynchid cestodes. These are the combination of (i) hooks 1(1') separated by a distinct space, hook rows terminating in inverted V-formation on the external face of the tentacle; (ii) a basal swelling and armature; (iii) the absence of three large hooks in the basal armature; and (iv) a metabasal armature consisting of half-spiral rows of hooks which diminish in size from the beginning (internal face) to the end (external face) of each row. Such a combination of characters suggests a new genus to accommodate them. We propose the new genus *Pseudochristianella* and that *T. minuta* of Southwell (1929) become *P. southwelli*, the type species.

Members of the family Eutetrarhynchidae having hooks 1(1') separated by a distinct space and only exhibiting V-formations of hook rows on the external face where rows end are: *Prochristianella* Dollfus, 1946; *Parachristianella* Dollfus, 1946. *Mecistobothrium* Heinz & Dailey, 1974 and *Trimacracanthus* Beveridge & Campbell, 1987. *Eutetrarhynchus* Pintner, 1913 differs in having no space between hook files 1 and 1', while *Oncomegas* Dollfus, 1929 differs further in having a single large hook at the base of the tentacle. *Prochristianella* possesses a basal swelling but can be quickly eliminated from further consideration because the metabasal hooks show an increase and subsequent decrease in size along the rows from internal to external face of the tentacle. The metabasal armature of *Pseudochristianella* resembles that of *Parachristianella*, *Mecistobothrium* and *Trimacracanthus* in that the hooks of each row decrease in size from the internal to the external face of the tentacle. The presence of a basal swelling in *Pseudochristianella* distinguishes it from *Parachristianella* and the absence of the triad of large hooks in the basal



Figs 1-9 *Pseudochristianella southwelli* gen. et. sp. nov. 1, internal face, basal region; 2, external face, basal region; 3, bothridial face, metabasal region; 4, basal armature, internal face; 5, metabasal hooks, numbers 1 to 4; 6, scolex; 7, entire worm; 8, terminal segment (mature); 9, metabasal hooks 1(1'). Line scales: figs. 1-5 and 9, 0.01mm; figs. 6-8, 0.1mm.

armature of *Pseudochristianella* separates it from *Trimacracanthus* (see Beveridge & Campbell 1987). *Mecistobothrium* has bulbs shorter than the bothridia (Heinz & Dailey 1974).

In *P. southwelli* the basal armature is distinctive in that it is restricted to the external face of the tentacle. The hooks on the internal face are merely a continuation of the metabasal region. This is probably of secondary importance because only the hooks of the external face in the basal region are modified in *Trimacracanthus aetobatidis*.

Dollfus (1942) pointed out several errors in Southwell's (1929) account of the species. Southwell (1929) stated that the species had also been recorded from *Urolophus testaceus* in European waters, but

Dollfus (1942) correctly observed that *U. testaceus* is an Australian ray. The error stems from a specimen in Southwell's collection (see BMNH 1977. 11.4.29) from *U. testaceus* from Moreton Bay, Qld. The specimen, though in poor condition, has been re-examined and identified as a species of *Eutetrarhynchus*, close to *E. geraschmidtii* Dollfus, 1974.

Acknowledgments

We wish to thank Dr D. I. Gibson and Mrs E. Harris for the loan of the Southwell material.

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**FIRST SOUTH AUSTRALIAN RECORD OF THE FOSSORIAL
LEPTODACTYLID FROG GENUS *UPEROLEIA* GRAY**

BY PETER BIRD

Summary

BRIEF COMMUNICATION

FIRST SOUTH AUSTRALIAN RECORD OF THE FOSSORIAL LEPTODACTYLID FROG GENUS *UPEROLEIA* GRAY

The frog fauna of South Australia is far richer than was assumed in an assessment made 30 years ago¹ when only 13 species were known to occur in the State. When the first South Australian field guide was published in 1966² the total had increased to 17, whilst a revision of that work in 1972³ recorded a further four species. The most recent estimate⁴ is of 25 species.

In December 1989 one of us (P.R.) travelled to the extreme northeast of South Australia. On 9.xii.89 a single specimen of a leptodactylid frog of the genus *Uperoleia* Gray was taken at Patchawara Creek in the vicinity of Patchawara Bore (27°20'00"S; 140°41'00"E), 45 km N of Innamineka. This is the first occasion that *Uperoleia* has been found in South Australia, although it is known from the adjacent portion of Queensland.⁵

Patchawara Creek is a small (ca. 8 m wide at the collection site), intermittent creek which contains several semi-permanent waterholes. At Patchawara Bore it was quite full following heavy rain in the area two weeks earlier. The maximum water depth was not measured but exceeded 1 m. Water flow was negligible.

Patchawara Creek rises adjacent to the Queensland border and flows west before emptying into Derawalkillie Waterhole. Together with the Beantree Creek system, the Patchawara Creek drainage basin occupies an area of about 900 km² abutting, but discrete from, the Cooper Creek drainage to the south. In exceptionally wet years however it is likely that waters from the Patchawara system reach Lake Goyder, part of the Coongie Lakes system on the North-West Branch of Cooper Creek.

Patchawara Bore is contained within the Mernie Land System of Innamineka Regional Reserve.⁶ Coolibahs *Eucalyptus microtheca*, Beantrees *Lysiphyllum gilvum* and occasional Native orange *Cupparis mitchellii* lined the creek channel. Otherwise the steep muddy banks were devoid of vegetation at the time except for occasional patches of an unidentified reed and accumulated flood debris 0.5 m above the waterline. The surrounding area comprised flat alluvial plains sparsely covered with grasses, low chenopods and forbs.

Two other frog species occurred at the collection site: numerous individuals of the tree frog *Litoria rubella* (Gray) calling from cavities and cattle pug marks in the banks, and about 10 water-holding frogs, *Cyclorana platycephala* (Günther) calling at the water's edge.

The specimen is an adult male. It has been deposited in the South Australian Museum and is registered R 34443. It was one of a group of at least four individuals first noted calling at about 10.00 p.m. from amongst flood debris less than 0.5 m from the water's edge. One or more individuals were heard calling whenever the site was visited over the following two hours. A recording of the advertisement call of the collected specimen proved to be too weak for sonographic analysis. However amplification by re-recording revealed that each call is composed of four pulses.

The temperature was not measured at the calling site but was probably about 30°C. At Moomba (100 km south) temperatures that day ranged 25-38°C.

A second group of about 10 calling males was subsequently located 250 m east at about midnight. This group was associated with a small patch of reeds and flood debris accumulated at the base of two Coolibahs at the water's edge, and with a patch of reeds on the opposite bank.

Measurements of the specimen (following the techniques of Tyler⁷) are: snout to vent length (S-V) 30.1 mm; tibia length (TL) 9.9 mm; eye to naris distance (E-N) 2.2 mm; internarial span (IN) 1.45 mm; eye diameter (E) 2.8 mm. Maxillae and premaxillae are edentate, the foot is unwebbed, the toes unfringed and the two metatarsal tubercles are moderately pronounced.

In life the dorsum was a pale greenish grey, with irregular dark blotches and flecks of olive brown, including a broad interocular bar and regular bars extending onto the limbs. The dorsal and lateral surfaces were densely covered with small, rounded tubercles. Those dorsolateral were conspicuously tipped with orange, forming narrow broken lines extending from behind the eye to the groin. Similar rows of orange-tipped tubercles formed short paravertebral lines above the anus, and dorsally along the tibia. Elsewhere the tubercles were tipped with white to pale apricot. The entire inguinal, post-femoral and pretibial areas were a rich orange red. The ventral surface was light grey, finely speckled with white. A photograph of the frog is shown in Fig. 1.

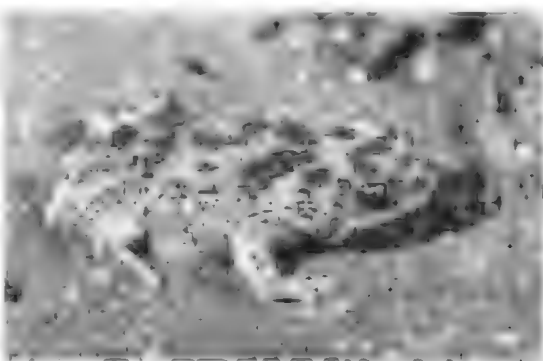


Fig. 1: *Uperoleia* sp. in life (South Australian Museum R34443).

Because two species of *Uperoleia* occur in the adjacent Bulloo Shire of southwest Queensland (*U. capitulata* Davies, McDonald & Corben, and *U. rugosa* (Andersson)) it seemed likely that the Patchawarra specimen would prove to represent one of them. *Uperoleia capitulata* as currently defined, and illustrated by its authors, has a smaller and characteristically blunter head, and possesses hypertrophied dermal glands. It also seems to be a smaller species: the largest adult male specimen known being 27 mm.⁸ The advertisement call of *U. capitulata* is unknown.

Uperoleia rugosa is another candidate. It is highly variable in size, with male individuals adult at as small

as 18.4 mm, but samples from arid localities are larger and can reach 32 mm.⁹ The advertisement call includes 3–5 pulses,^{9–10} and although most specimens are rugose and have fringed toes, they can be smooth and unfringed. A larger series of specimens from Patchawara Bore will permit osteological and other cryptic features to be examined.

Given that we have just one specimen, caution dictates that it is early to be certain that it is *U. rugosa* or *U. capitulata* that occurs in South Australia.

The discovery of *Uperoleia* brings the number of species recorded from the North-east to nine, and confirms that

this area has the richest frog fauna in the State.

It is of interest to note that *Uperoleia* was not located during the recent extensive biological survey of the North-West Branch area centred on Coongie Lake, only 50 km west of the collection site.¹¹ Considering that this survey resulted in the collection of all species then known from the North-east including one new record for the State, we conclude that *Uperoleia* does not occur there; its distribution in South Australia may be extremely limited.

We are grateful to the National Parks & Wildlife Service for a permit (No. C02501) to collect within the Innamincka Reserve.

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**COMMENT: PRELIMINARY INVESTIGATIONS OF BEACH RIDGE
PROGRADATION ON EYRE PENINSULA AND KANGAROO ISLAND**

BY C. R. TWIDALE & J. A. BOURNE

Summary

BRIEF COMMUNICATION

COMMENT: PRELIMINARY INVESTIGATIONS OF BEACH RIDGE PROGRADATION ON EYRE PENINSULA AND KANGAROO ISLAND

In the course of discussion of beach ridges on Eyre Peninsula and Kangaroo Island,¹ brief mention is made of shore platforms and their implications for sealevel change. Two statements based on earlier reports^{2,3} concerning shore platforms are questionable. (p.62; p.56).

The first is that all of the shore platforms examined on the west coast of Eyre Peninsula possess "a single active platform surface"¹ (p.156). We take issue because the impression conveyed is that only one platform is developed within rocky shore profiles. As recorded earlier⁴ flights of platforms are commonly developed within the tidal zone. They are typically separated by low cliffs a few tens of centimetres high. In addition platforms of limited areal extent occur near or above high tide and even storm tide level, and some stand even higher, though all are located within the spray zone. The situation described from parts of Kangaroo Island¹² is commonplace also on the west coast of Eyre Peninsula.

Second, in the 1986 report² it is stated that at Pennington Bay "a Pleistocene platform is fronted by two Holocene platforms at different elevations . . . The upper platform . . . lies 50 cm above the lower platform . . . The difference in elevation . . . may be the result of a slight fall of sea-level (50 cm) producing a lowering of the level of saturation and hence platform erosion". The site is illustrated² (p. 59) and it is suggested that the highest platform "most likely represents the 120,000 yrs BP Pleistocene sea-level", that the intermediate platform, standing 2.5 m below the "Pleistocene" feature is of early Holocene age, and that only the (lowest, 50 cm below the intermediate form, is presently active.

We find the suggestion that each platform relates to a distinct and separate sealevel surprising. Some years ago the same interpretation was proposed in explanation of platforms and other alleged coastal features in the Adelaide area and on Yorke Peninsula.^{3,6} It was then claimed that stands of the sea differing by as little as 42.16 cm could be distinguished on the basis of a range of forms and deposits collectively described as "former coastal features"⁶ (p.291). These conclusions were challenged at the time⁷ partly on the grounds that the Gulf's region of South Australia is, and long has been, tectonically active, rendering present elevations an insecure basis for correlation or dating (a tilt of as little as 1" implies a vertical difference of some 18m/km); partly because the central Mediterranean region that provided the basis for dating and correlation was even then known to be and has been tectonically unstable, so that correlation on elevation alone was invalid;⁸ partly because some of the stratigraphic evidence was suspect.

More fundamentally other workers^{9,10} had earlier pointed to evidence strongly suggesting that processes additional to wave attack were active in platform development, and that the flights of platforms they had observed on the coasts of NSW and Victoria have developed simultaneously and in relation to the one present sealevel. Our observations on many parts of the South Australian coast have led us to similar conclusions, though structure and the etch factor complicate the profiles

developed on many rocky shores. Thus the platforms in granite and gneiss exposed around Point Brown, on the Westall Peninsula and at Point Drummond for instance are etch forms.^{4,11,12} Separating out such complications however there is clear indication that pool weathering^{10,13,14,15} contributes to platform development not only in the tidal range but also above it, within the spray zone; and that though pronounced on calcarenitic coasts, its effects are not limited to that lithological setting. For example, the serrated platform at Hallett Cove, just south of Adelaide is developed on folded siltstone. The platform is an entity, but included within the whole are several flats each a few metres square that vary in elevation by up to one metre. They are unlikely to reflect lithological contrasts as they occur along strike, and they cannot be due to wave abrasion as many are protected to seaward by minor strike ridges. Some of the flats formed at or near high and storm tide levels are quite extensive,⁴ but those within the spray zone are small, though distinct. Thus spray pool generated flats a few metres diameter stand about 8 m above the high tide level at Wellesley Point, near Elliston. Developed in calcarenite, the pool floors are remarkably flat. They commonly carry seawater (and rainwater after falls) and small shells, and the sidewalls are to a greater or lesser degree overhanging as a result of the dissolution of the calcarenite by standing waters. Such pool floors gradually extend laterally and eventually coalesce with one another to form a platform that includes flats at slightly different elevations.

For these reasons we suggest platforms are related to sealevel only in a general way. Each platform does not necessarily represent a distinct and separate sealevel.^{16,17} Flights of platforms do not necessarily imply changes of sealevel. That flights with similar components and vertical separation occur at different sites along the coast may merely imply that similar sets of processes are at work on each.

We accept that some of the platforms preserved on the coast of Eyre Peninsula are demonstrably of Pleistocene age. For instance that described from Point Collison³ (p.136) is clearly of the order of 40,000 years old. But others, even those of similar elevation with respect to present sealevel, cannot be correlated automatically and dated by comparison with such dated sites. The high platform at Pennington Bay for instance is still within range of high and storm tides, and is certainly touched by spray. The cusps developed in the low cliff to seaward of the platform² (p. 59, Fig. 4.15) surely prove scouring and solution by seawater at the present time, and the shingle located at the base of the backing cliff may also be related to high and storm tides.

We found nothing to disprove the suggestion that flights of platforms are being formed simultaneously in relation to modern sealevel. Jutson, Hill and many others would be astonished at the suggestion that each and every shore platform is related to a separate and distinct sealevel and that shore platforms can be correlated and even dated on the basis of their elevation. On the other hand, we agree wholeheartedly with the conclusion that "shore platforms are highly questionable indicators of sea-level"¹ (p. 156).

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**REPLY: PRELIMINARY INVESTIGATIONS OF BEACH RIDGE
PROGRADATION ON EYRE PENINSULA AND KANGAROO ISLAND**

BY A. D. SHORT, R. C. BUCKLEY & D. G. FOTHERINGHAM

Summary

BRIEF COMMUNICATION

REPLY: PRELIMINARY INVESTIGATIONS OF BEACH RIDGE PROGRADATION ON EYRE PENINSULA AND KANGAROO ISLAND

Twidale & Bourne¹ (this issue) are correct in drawing attention to the problem of relating shore platform elevation to sea-level and in particular the interpretation and causes of multi-level platforms. In this reply we will not attempt to deal with the still poorly understood area of shore platforms genesis, rather as our paper was dealing primarily with beach ridges with only passing reference to the Pennington Bay shore platforms we will expand on the rationale for our shore platform interpretations in light of Twidale & Bourne's comments. Like Twidale & Bourne we thoroughly agree that "Juston and Hill and many others would be astonished at the suggestion that each and every shore platform is related to a separate and distinct sea-level ...". The suggestion that "each and every" is not ours, we merely suggested that one platform at Pennington Bay "may be a result of a slight fall in sea level" and this point we still support. In our paper² (p.58-59) and report,³ we did not by intention or implication suggest any extrapolation of the Pennington Bay conclusion beyond that location either to the hundreds of other calcarenite platforms examined in our studies^{4,5} and particularly not to platforms in different lithologies and settings. Consequently the range of evidence cited by Twidale & Bourne (this issue) relating to the origins of "flights of platforms" is largely irrelevant to the present argument as they, by and large, represent very different lithologies. Our rationale for the Pennington Bay platform is that it is formed in massive, though laminated Pleistocene dune calcarenite. Based on examination of hundreds of platforms across southern Australia we would argue that the active shore platforms in such lithologies in exposed locations are always intertidal lying close to

mean sea-level. They are also remarkably horizontal, though often heavily potholed. In contrast platforms in other lithologies may be intertidal (e.g. shales) or supertidal (e.g. basalts, sandstones) or non-existent (e.g. granites) and depending on the geotechnical qualities of the particular lithology may indeed have "flights of platforms".

At Pennington Bay are three very distinct platform levels formed over a 30 m shore perpendicular distance and running for about 200 m alongshore. The uppermost (~3 m MSLW) is heavily degraded and assumed to be Pleistocene in age,⁶ the 10 m wide lower most (~0 m MSLW) is assumed to be the active intertidal platform, while the 5 m wide mid (~50 cm MSLW) is the one in question. The lower two platforms are in close proximity (15 m shore perpendicular distance) with an abrupt 50 cm high scarp separating the two. They both are formed in massive calcarenite and truncate the dune laminations. We would therefore argue that causes other than contemporary processes (i.e. differential levels of saturation, wave exposure, etc.) or lithological control has produced the levels. As originally suggested by us one other cause "may" be a slight fall in relative sea-level. We would still argue this may be a cause in this location.

The resolution of this problem will however await research which will go beyond attention to the role of the level of saturation in controlling active platform formation.⁶ Until studies of rocky coasts move beyond mere description and robust morphodynamic models of platform evolution including the geochemical causes of accelerated cliff retreat are available, the now century old debate⁷ on platform genesis and interpretation will continue.

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**CYCLORAN MAINI AND NOTADEN SP.: ADDITIONS TO THE FROG
FAUNA OF SOUTH AUSTRALIA**

BY G. R. JOHNSTON

Summary

BRIEF COMMUNICATION

CYCLORANA MAINI AND NOTADEN SP.: ADDITIONS TO THE FROG FAUNA OF SOUTH AUSTRALIA

Twenty-six species of frog are known to occur in South Australia^{1,2}. About half of these species are restricted to the mesic southern regions of the state, where the fauna is relatively well known. The other half occur in the xeric northern regions of South Australia and their distributions and biology are poorly known. Collections of these desert dwelling frogs are usually made fortuitously because their activity is sporadic, in response to unpredictable rains.

This note reports opportunistic observations made when heavy rains fell in the north of South Australia during March and April 1989. It records the occurrence in South Australia of two species of frog previously unknown from the State.

Five *Cyclorana maini* were observed at the point where the Stuart Highway crosses Indulkana Creek (26°59'S, 133°23'E) on 15.iv.1989. All individuals were on the road at night during rain. These specimens were unusual in lacking a dark lateral head stripe, but in all other respects agreed with the type description.³ One specimen was collected and lodged in the South Australian Museum (SAM R34311) (Fig. 1).

Large numbers of a *Notaden* species were heard calling together with a *Neobatrachus* sp., in pools of water 3–400 m from the side of the Stuart Highway between 23 km N of Marla and the Granite Downs turnoff (26°58'S, 133°23'E) on 15.iv.1989. This species was also calling in a large pool of water immediately S of the Oodnadatta road at the township of Marla (27°26'S, 133°43'E) on 22.iv.1989. No specimens could be collected, but the call left no doubt as to the generic identity of these animals, being an owl-like 'oo-oo'. Unfortunately, the species of *Notaden* are not distinguishable by call so specific identity of the *Notaden* occurring in South Australia remains in doubt.

The discovery of *Notaden* in South Australia extends the known geographic range of this genus 350 kilometres southwards from the closest record of *N. nichollsi* at Chinaman Creek, N.T. (23°42'S, 132°30'E) (Northern Territory Museum R5397). The discovery of *C. maini* in South Australia extends the known geographic range of this species 330 kilometres southwards from the closest record 27 kilometres S of Alice Springs (23°57'S, 133°55'E).⁴



Fig. 1. *Cyclorana maini* from Indulkana Creek, S.A. (SAM R34311).

As *N. nichollsi* and *C. maini* occur extensively in the Northern Territory and in central Western Australia,^{4,5} their occurrence in northern South Australia, although representing significant range extensions, is not surprising and of little biogeographic significance.

C. Daniels & P. Dempsey assisted in the field. M. Davies provided the figure. M. Davies & M. Tyler made helpful comments on the manuscript.

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